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THE
INSTITUTION OF PRODUCTION ENGINEERS

SESSION 1924–1925.

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1922–23. MAX R. LAWRENCE, M.I.M.E., M.I.A.E.
1923–24. J. D. SCAIFE, M.I.Mech.E., A.F.R.Ae.S.

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THE
INSTITUTION OF PRODUCTION ENGINEERS.

THE THIRD ANNUAL GENERAL MEETING AND THE FIRST ANNUAL DINNER.

THE Annual General Meeting and first Annual Dinner of the Institution of Production Engineers was held at the Engineers Club, London, on Saturday, September 13th, Mr. J. D. Scaife (President) in the chair.

THE PRESIDENT in opening the meeting said :—My task is a brief one because in a few minutes Mr. Fisher will be taking my place as President. I think during the year that has passed we have moved forward a good deal. We have established ourselves just a little more firmly and I believe that during the coming year we shall move forward rapidly. I welcome Mr. Fisher as my successor, and I have every reason to think that he will do even better than either Mr. Max Lawrence or myself have done. Indeed, I hope that every man who occupies the position of President will do better, in turn, than his predecessors. I ask Mr. Fisher to take the Chair.

MR. FISHER, addressing the meeting said :—In expressing my appreciation of the compliment this Institution pays me in making me President for the ensuing session, I do not intend to treat you to a lengthy peroration. The few remarks I have to make will be kept as brief as possible. If this is a break-away from accepted courses, it is a break-away appropriate to the occasion, for production engineers primarily exist to save time, or at any rate, to see that no time is wasted. First and foremost, we must be time savers. Before speculating as to the future, however, we may perhaps pause a moment, and glance back. In this connection, I may say I count myself extremely fortunate in being elected to office at a period when we are able to look with some satisfaction on work done. Not only is this the case, but it is work well done. We have, in shop parlance, "broken the back of the job." The Institution of Production Engineers has been well founded and is now an established fact. At the present date it is scarcely even new, although it is, of course, young as engineering institutions go.

For all of you who have been associated with the Institution from its inception there is a large measure of satisfaction to be secured from the knowledge that the future is no longer in doubt. Further, neither is there now any debate as to its usefulness. The very essential and important character of the work it is undertaking is generally recognised.

In its way the Institution was rather a bold conception, constituting as it did an addition to an already large number of similar

organisations. Those of us who believed in its future and associated ourselves with it from the commencement, all, I think, had a feeling that like other great schemes it might not come to fruition. At that time we sometimes spoke, perhaps, a little diffidently of the Institution, its work and prospects. Now, however, we may look around us with satisfaction—not only on our past work but on the Institution's financial position, our prospects for the future, our membership, and the immense development that lies ahead of us.

While I personally am more of a "past" production engineer at the moment, I always look back with a happy memory to "shop" days, and I feel that production men should no longer be diffident as to the value of their work and position. Their job has always been a great and important one, although this fact has not been so well recognised as we might have wished. In the production man's daily routine he has to bring to bear a wide knowledge of the trade. His occupation is one of intense concentration, originality, and detail.

It is probably because production men have in the past been so closely applied to their jobs, that they have not pressed for a greater measure of professional recognition. From now onwards, they may take a wider outlook and claim for themselves no inconsiderable place in the industrial world. The Institution comes boldly forth to claim for them that position, and as an educative force for members themselves the Institution does, and will continue to perform, an invaluable work.

As time goes on our members will be ranked more and more as essential units in that vast production which engineering of all classes typifies. In essence, bridges, ships, locomotives, aeroplanes, etc., are production jobs, just as much as all the innumerable small necessities such as typewriters, gramophones, locks, taps, valves, fittings, etc. All are wholly or in part our work, and modern life would not be possible without the many things upon which the manufacturing engineer concentrates.

The vital point is that as production engineers, we follow the important pursuit of making things economically. Our work as individuals is a vital one, and so, therefore, is our work collectively in this Institution, which is to advance the science of manufacture by improving and devising production methods.

A subsidiary, yet highly important task which production engineers will find they have to undertake is the education of the firms that employ them. Despite the progress that has been made in the way of organisation and management, an immense amount still remains to be done. It is almost necessary nowadays to apologise for mentioning the word "organisation," the whole subject has been so done to death. It is, however, far more in theory than in practice that the field has been exhausted, and in many quite important works a start has scarcely been made in a practical direction.

One of the most important phases of organisation is, of course, economical operation planning, and the outlook prompting this planning might well be carried to other departments. We can summarise it in a word, "forethought." Commercial success will be found not only in the planning of machines and operations, but in scheming

in advance generally, both in work and policy. It is impossible to overstress the importance of looking ahead. Intelligent anticipation, scientifically applied, will do much towards solving difficult problems, and, in addition, will prevent others arising. A highly efficient commercial organisation is essential to feed a well-planned modern works, and the production engineer necessarily relies on being supplied with work in a steady flow if he is to give of his best in the shops.

As production engineers we put forward the earnest plea that we be backed by proper but unextravagant organisation so that we may plan ahead in confidence. There is more time wasted, and more money spent doing things wrongly than in not doing them at all. Clear thinking must precede all profitable action.

One difficulty that is being experienced in works of a really efficient character is that of securing adequate and suitable labour. Despite unemployment, the sound, skilled worker cannot readily be found and, when found, retained. He exhibits a disconcerting preference for the "easier" shops. It would, therefore, seem that some national concerted effort is necessary in technical training in order to increase the supply, and also some co-operative effort towards bringing the great majority of firms to an equally efficient working condition. If this were done there would not be so many "easy" shops to turn to. When men find themselves in a well-planned shop where they have to work hard, there is a tendency for them to move off to the more easy going concern where they are not kept at quite so high a pitch of activity. The object should be to eliminate the too easy-going shop altogether.

In many works there is still a great deal too much hand work, and although this fact provides much scope for the talents of the production engineer, yet it is bad in a competitive industry like ours. By getting to work on manufacturing problems of this kind we shall reduce the cost of our finished products, and so assist our great manufacturing concerns in securing and maintaining their proud position as the makers of the best engineering products in the world. This is a task of such importance and magnitude that I visualise the Institution in the years ahead as rivalling, perhaps transcending in size, all other engineering bodies. This should not be too high a flight of fancy, as after all we embrace every branch of the engineering industry. The products of the electrical, mechanical, hydraulic, and machine tool industries are all primarily production jobs, and all these industries therefore, are for the Institution, potential sources of membership.

In a co-operative and co-educative way amongst ourselves a vast future lies ahead of the Institution. Production men in the various sections of engineering have still much to learn from one another, and it is to be hoped that more and more engineers in the different industries will join up as members of our Institution.

It is now a platitude to refer to the importance of any and every detail that will assist towards cheap yet good grade production. While this fact has not always been so fully recognised as it is to-day, it is now generally agreed that this is a vital matter for us as a nation, and we have tangible evidence of this recognition in

many ways. The Engineering Standards Association, for instance, have just produced their report on fits and tolerances. This report was issued in July of this year, and it is hoped that the Association will turn its attention more and more to standardising those particular details that touch upon and facilitate the great work of interchangeable repetition manufacture.

As to the past work of the Institution of Production Engineers, those who have seen our proceedings will have gathered some idea of the value and diversity of the papers presented to us. The Institution Council would like to see more of our great firms backing the work of the Institution, as however good our position it will never be such that improvement will not be welcome. We must also refer to the activities of our employment bureau, which has been instrumental in placing many suitable men in touch with opportunities for the best employment of their talents.

It is gratifying to the Committee who deal with applications for membership to observe the keen interest that is shown in the Institution's work by engineers abroad. We find, in fact, that the foreign members are probably the keenest of all. We have enthusiastic members in the United States of America, in Queensland, India, and other far-distant lands.

For the forthcoming session an excellent programme of papers has been arranged, but the present moment seems, nevertheless, a suitable one to draw attention to our interest in highly specialised jobs. We should welcome sound papers from experts in welding and cutting, die-casting, extrusion, rolling, hot stamping, moulding, etc. Those of you who are familiar with any of the specialised processes employed in the engineering industry or are acquainted with others thus engaged, would assist the Institution in its work if you would make the Institution's wishes in this connection known.

In conclusion, I can only say that I appreciate the honour of being your President, and you may rest assured that no effort will be spared during my term of office to promote the progress of the Institution and assist the production engineer.

The other business of the meeting then followed, and, this completed,

Mr. R. H. Hutchinson, proposing a vote of thanks to the retiring President, said :—I do not think this meeting should break up without passing a very cordial vote of thanks to our past President, Mr. Scaife, whom we are not losing as a member of the Institution. I have had the honour of being elected to the Council during the past twelve months and I can honestly say that I have never received from any President the same amount of kindness and help that I have received from Mr. Scaife. Mr. Scaife does not live in London, where all our Council meetings are held, nevertheless he has shown extraordinary punctuality at meetings. Under our retiring President we have made a bound forward during the past twelve months, and I can assure you that this forward move is probably greater than you realise at the present moment. There is one other matter which I am sure also merits your attention before the meeting closes. We have changed secretaries during the past twelve months, and it is only fair that attention should be called to the enormous amount

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The first annual dinner of the Institut

of the Institution of Production Engineers.

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of time and work put into the affairs of the Institution by our past secretary, Mr. Davey. For that work we owe him our deep gratitude and therefore I have the greatest possible pleasure in proposing a hearty vote of thanks to our retiring President, Mr. Scaife, and our retired secretary, Mr. Davey.

Mr. Hales :—I have very great pleasure in seconding the vote of thanks. I have known Mr. Scaife for many years, and I feel with Mr. Hutchinson that Mr. Scaife has done wonderful work during his year of office. I very well remember a year ago when Mr. Scaife was proposed as President that there was some measure of doubt on the part of certain members as to the position which might arise due to the President living so many miles away from London. It was thought that it might be impossible for him to put in the necessary time with us. I can endorse, however, Mr. Hutchinson's remarks, for right through the session Mr. Scaife has always been first at the meetings and last away. Everyone on the Council knows that he has worked wonders, and I have no doubt that our future Presidents will carry on the work equally successfully. The vote of thanks was carried with acclamation.

Mr. Scaife, replying to the vote of thanks, said :—It is extremely kind of you to say all these nice things about me, but what I have done for the Institution has been done with a will because I have enjoyed it. I can only hope that it has been useful, and I hope to continue my activities for the Institution in years to come.

This closed the business of the Annual General Meeting.

Annual Dinner.

The Annual Dinner followed at which Mr. W. L. Fisher, the new President, took the chair.

After the toast of "The King" had been duly honoured,

Sir Herbert Austin proposing "The Institution" said :—In the first place I should like to acknowledge the compliment you have paid me in asking me to propose this toast. As a matter of fact, until I got your invitation to attend this function I must confess that I knew very little about the Institution of Production Engineers. That is my fault, of course. At the same time the Institution has only been in existence a short period, and perhaps you will accept that as an excuse for my not knowing very much about it. If I do not know much about it, it is quite possible that others will be in the same position, and therefore I think it behoves those associated with the Institution to advertise, not in the way we advertise in the papers, but at any rate to let people know of the existence of the Institution, its objects, its aims and what it has already done. During the past few years there has been quite an epidemic of institutions. I remember having an argument with my old friend, Mr. Wade, who is here to-night and who takes a very great interest in the Institution of Engineering Inspection; I may also remark that I myself do a little work in this connection. I am Chairman of the Local Board of the Institute of Transport, though I do not suppose there are many present who know much about that. There are also many other institutes such as the Institute of Metals and others, all of which have grown up in the past few years, and it

sets one thinking whether all these institutes are really necessary. I have had a lot of argument with my friends on that particular subject. I suppose that most of the institutions to-day outside the Institutions of Mechanical, Civil and Electrical Engineers in this country are suffering to a very large extent because of the small membership, and one of the great difficulties they have to face—at any rate the members themselves tell me this—in making the membership more attractive, is the fact that it is so difficult to get members from the country up to the London meetings to the reading of the various papers. Therefore some of the stronger institutions have adopted the plan of establishing local branches. The Institution of Electrical Engineers have done the best in that direction, I believe. They have something like fourteen branches throughout the country, which is more than either the Institutions of Mechanical or Civil Engineers, and by that means I believe they are adding very considerably to their membership and naturally, also, to their funds. All bodies such as the Institution of Production Engineers must have funds, you cannot do anything without money.

There are other ways in which, I think, perhaps, improvements might be effected. I have discussed this matter on very many occasions in other places, and I mean by some amalgamation of the efforts of the various institutions. I said before that one wonders whether all the various institutions are necessary. I suppose they are or they would not exist, but I really do think that we should get very considerable advantages if some of our institutions were on some occasions, even if not on all, to combine their efforts so as to make their doings more interesting throughout the various localities of the country. I think, as a matter of fact, the work of an institution loses very much of its value because of the difficulty of getting sufficiently good and sufficiently energetic debates on the papers read before it. As a matter of fact, it is quite as easy, I suppose, and perhaps even more interesting, to take the printed paper that is given before an institution, and sit down at one's leisure and study it. That is the way I generally do it—as a matter of fact that is the only way I can find time to do it—but that does not give you the value you get from attending a meeting because when you have read the paper and the debate on it you have merely got the small amount of discussion and criticism which arises at the moment, whereas if the paper could be given under better conditions and the debate continued over one or two meetings, the value would be considerably increased. It would not be limited so much as it is at the present moment to the views of the person reading the paper or giving the address, with perhaps one or two criticisms which were the best which could be found among the particular members of the Institution present. I am personally very interested in the doings of the Institution of Production Engineers, because I put in most of my time trying to build motor cars to compete with various other firms in the country and abroad, and I realised very many years ago that the cost of production was the chief difficulty. I had the advantage and very great pleasure about eighteen months ago of visiting the United States for the first time, and like many other people who visit the States

for the first time I did see some very remarkable things. One hears remarkable things about the doings of American engineers and the wonderful factories and marvellous organisations they have and how much we are in the background. Well, I certainly did see some very wonderful things, and I would like the opportunity very much to go over and study them at my leisure, because my visit was rather a hurried one. Despite this, I did learn a lot; not a lot about mere machining, and rates of machining, although one did see some very high speeds, but there were other things altogether outside the mere cutting of metal that one could get very considerable knowledge from. I saw the famous Ford shops and various other shops of a smaller character, but the point that interested me and made me marvel most was the way in which everybody in the establishment seemed to be trying to be doing their best (hear, hear). I think many who have had training in intensive machining will probably find fault with some of the things done out there; many operations seemed to be crude and rough, but as a matter of fact, whether they were doing work to fine limits or work of a rough character, everybody seemed to be intent on getting it done. If the Institution of Production Engineers through the influence of its work could get the same conditions obtaining in this country, I am quite confident that with our better quality of workmen, and, I think, with equally good conditions—other perhaps than a certain amount of advanced machinery—we should have no reason whatever to fear competition from other countries (applause). As a matter of fact, I think you must agree that we do lack that combined individual intensive effort—if you have not seen it you have read of it—that one can get in the United States. The men are all paid piece work, and there are certain psychological conditions existing over there which would be difficult to put into operation here; but at the same time those who worked in the shops during the war, without limitation of output, must have noticed that almost unconsciously there was built up an atmosphere in the shop of a resolution to get a much larger production than obtained before in the manufacture of similar articles. Therefore, I am quite confident that if the work of the members of this Institution could be applied and successfully applied to bring about results similar to those now obtained in the United States, this country would not have very much to fear as to the future.

I believe, as a matter of fact, that we are just entering on a period of transition, and I believe that this country will shortly realise that we have got to throw overboard these limitations on output. If you will let me perhaps speak a little politically, though perhaps I should not do so, I think at the present time everyone present must have noticed that for some time past there has been an effort throughout the trade unions and other similar organisations to limit output with the idea that if only output is reduced individually there will be work enough to go round and that we shall be able to employ very many people who are at present without work. As a matter of fact, I believe that idea will break down. It will break down, perhaps, after a very unpleasant process—a process that, somehow or other, it seems we must go through in order to be

able to realise what is necessary. At the same time I do believe it will break down, and that we must realise as a nation that we have to broaden our views and do as others do who have made a success of their efforts. We shall then be able from production—intensive production—to do as well as our neighbours. We in the motor trade are, what they say in the North, "up against it." We are going in the next six or eight months to find our level. We shall be able to measure the power of our opponents. Some will throw down their cards, and we shall have to try and keep all the trumps we can for the final deal. I am not at all despondent as to the future, but I do think that in the next six months we are going to be taught a lesson, and shall realise what is necessary to be done. I believe we shall meet the position when it comes. We may be a little late; we may be a little slow; but at the same time I am confident that the energy, the ability, and the determination of the English race will conquer in the end.

I am extremely pleased to be present this evening. I see around me several faces that I have met under other conditions, and I see one or two that I have had long arguments with, not on production, but on other matters of equal importance at the time; and I should like to say a word, before I sit down, of encouragement to the members of the Institution. I believe the work of the production engineer is going to be appreciated in the future. This work to a large extent is new, and in many works the value of it is not appreciated. As a matter of fact, you will find in many works a certain amount of antagonism to the imposition of what is regarded as another policeman. There are in most works three departments coming under this head: one is the costing department, generally disliked; the other is the planning or efficiency department; and the third the inspection department. I would not like to say which is the worst of the three. (Loud laughter.) Perhaps in the circumstances of this evening, and seeing that there are present those who are engaged in each of the departments, I had better say they are all alike; but I really do think, whether they are good, bad, or indifferent, they are all necessary, and that no modern works can be successfully carried on without all three of them. I think the costing department in a modern works run on business-like lines is appreciated, and is not now looked upon as it was in the past, as an unnecessary evil. It can be a very great help to all branches throughout the works. I think the same about the planning or efficiency department. If that is conducted by men who are patient and have broad-minded views of their work, then this department can be of the greatest value throughout the factory.

Once again I wish to express my appreciation of the honour you have done me in inviting me here this evening, and I now ask you to drink the health of "The Institution of Production Engineers."

Mr. J. D. Scaife, replying to the toast, said:—I am honoured by our Council in being asked to say a few words in reply to Sir Herbert, and now that we have so many eminent engineers with us, I think we may safely say that the Institution is under way. We have had some years of anxiety, and we have had some hard work in getting the Institution going, but I think we can say that

it is under way now. After Sir Herbert Austin's very helpful and comprehensive speech, I feel it is up to me to answer a few of the points he has raised; but I would like to say this: that if I do not answer them all, we have some members present who could have done so if they had been in my position. It is not because we cannot answer them that we do not. (Laughter.) First, as to what are the objects of the Institution. If you read the Articles of Association you will find most of them there. I think I can best explain the objects of the Institution by giving my own experience of it. All my engineering life I have been engaged on the production and the practical side of engineering. Others have been engaged on the scientific side. I have been engaged on that side of engineering which took the work of such engineers and endeavoured to put the fruits of their work in the hands of the man in the street at the lowest cost. The field of the Institution of Mechanical Engineers is a very wide one, and the history of the engineering of the world can be found in the records and Proceedings of that Institution. They have a wide field of engineering to cover, but there is also a wide field for our own endeavour.

Sir Herbert Austin's name is known throughout the world as an engineer, but suppose that, although Sir Herbert Austin had been an equally good engineer, yet his cars had not been known throughout the world, and suppose that along with other engineers he attended the meetings of the Institution of Mechanical Engineers and joined in the discussions there, I venture to say that any of the young engineering students from a university who had had no engineering experience whatever would outshine him. They could discourse on the deepest science of heat engines, entropy, and so on, and they would cut more ice, to use the vernacular, than any of the eminent gentlemen whom we have here to-night were they present *incognito*. I therefore say, with all due respect, that the Institution of Mechanical Engineers deals more with the scientific side of engineering, and is not much impressed by we shop engineers who take their work and study its manufacture.

We have heard a lot about the manufacture of steel in Sheffield lately in various papers. Most of us have to use Sheffield steel, and I know a good many of the manufacturers of steel in Sheffield. Some of them are friendly towards myself, and some are otherwise. (Laughter.) I had the pleasure at one time of going on the Continent and seeing steel made—no, not made; it is "made" in Sheffield, but it is "manufactured" on the Continent. Very few people in the foreign works know anything about steel. There are one or two who know as much as there is to know at present about it, but the rest of the people do not know anything. The whole job of steel production is cut and dried, and the methods are organised just as I like to see them when things are to be produced in a factory. I am sorry to say that things are not done on the same lines in Sheffield. I mention that, not with the idea of running down Sheffield steels, because most Sheffield manufacturers turn out good stuff. The point is, they do not do it on "factory" lines; and until they do manufacture steel on the same lines as they do on the Continent, they will not make the stuff at

the price or as good. I told one of the experts when I was over there that it was the labour he had which enabled him to manufacture so cheaply, but his reply was that it is nothing of the sort, and he added that with his organisation he could make steel in England at a less price. That was thousands of miles away on the Continent. As I say, I do not mention this to disparage Sheffield, but I give it as an instance of what the Institution of Production Engineers is aiming at, *i.e.*, we want the factory system over here. I should like to thank Sir Herbert and the other guests for their attendance, and we specially thank Sir Herbert Austin for his interesting remarks. (Applause.)

Mr. R. H. Hutchinson, proposing the toast of "The Visitors," said:—It is with very great pride that I propose this toast—pride in the sure knowledge that upon the solid foundations which by their grit and tenacity our Council have laid, we shall see built up an Institution worthy of taking its place beside the three great Institutions which Sir Herbert Austin has mentioned. This may seem to be an idle boast, but there are many here to-night who have the sure knowledge that it will become the certainty of to-morrow. Where is there an industry into which the activity of the production engineer does not extend? Sir Herbert Austin expressed some doubt as to the meaning of the term "production engineer," but we take it as meaning an engineer who holds a position of responsibility in the manufacture of any article by engineering or scientific methods. (Hear, hear.) We include in our membership engineers from all over the world, India, Queensland, the United States, South Africa, etc.; we also include engineers drawn from a tremendous variety of trades such as the manufacture of steam turbines, electrical generators, the finest gauges for the manufacture of standards, motor cars, aero engines, sewing machines, shipbuilding, etc. Whether it is ships or sewing machines, motor cars or gramophones, turbo-alternators or magnetos, there are a tremendous number of problems of interest to the production engineer, common to all of them. Works general organisation; shop planning; methods of production; types of machine tools to be used; methods of inspection; manufacturing limits; progress; transport—and in fact innumerable points of vital interest to those responsible for the production of the needs of mankind. We hold that the production engineer can be drawn from all of them. One often hears the old adage that "necessity is the mother of invention," but I venture to say that if the sage who was responsible for that saying were here to-day, he would say that the production engineer is the father (laughter), for is it not the fact that it is the genius of the production engineer which is invariably responsible for the conversion of the subject matter of the invention into the solid matter of the product? (Hear, hear.) The production engineer has brought within the reach of those of moderate means articles which a few years ago were within the reach only of the very wealthy, and this being so, are we not entitled to the firm conviction that the Institution will, within a few years, become the great stronghold and the hub of the profession of production engineer? (Hear, hear.) I claim we are as much entitled to be called a profession as the doctors,

the lawyers, or any of the jealously guarded professions of our land. Sir Herbert Austin mentioned that he thought that if only papers could be debated more than they are, it would be better. We have the idea of having a series of very short papers—what we are going to term ten-minute papers—and we are going to get people of eminence in the particular branches of industry to open the discussions. These discussions will be circulated amongst all our branches, and they will be debated and discussed in turn in each and will be continued and carried on into the next branch, and so on. We think that to some extent this is a new idea, and I believe it will bear very great fruit indeed. Then, again, we are preparing a series of debates and lectures and papers for our younger members which are designed to be of a very special and instructive nature. We propose to look after our younger members and to encourage them and bring them along. They are what I might call student members who one of these days will make good full members of the Institution. Several new provincial branches are just about to get under way. We have a few already, but as time goes on it is our intention to extend them still further, and we hope to live to see the day when every works in the country has its own technical or debating society affiliated through the provincial branch with the London centre. It is with very great pleasure that I now ask you to drink to the health of our guests.

Mr. F. R. Wade, replying to the toast, said :—It is a very great honour to be with you to-night for several reasons. The first reason is because I feel that the work which you are endeavouring to do is, as Mr. Hutchinson has rightly said, one of very great importance and an importance which is not generally recognised. As President of the Institution of Engineering Inspection, I feel that we have a kindred attachment and that we are working on the same lines. I am a member of other institutions, and I feel that they can be termed the vertical sections of the engineering profession, whereas ours and yours can be regarded as the horizontal intersections combining all the aims and objects of the various technical institutions, and combining them for the good of our country. It is very excellent indeed to have technical institutions which develop and disseminate knowledge of technical work, for that knowledge is oft-times like the knowledge of the very clever man who never put it to practical use. It is of great value as an asset to be put down in text books, but so long as it stops there it does not add to or strengthen the wealth of our country at all. Some two or three years ago I had the temerity in the Institution of Mechanical Engineers to call a general meeting. I was received by the President and Council at that time with very black looks indeed and told to mind my own business. However, we held the meeting, and I tried to induce the Institution to formulate a policy which would assist manufacturers to carry on production work on a commercial basis to enable them to establish their businesses in such a way that they could meet foreign competition. I was told, however, that that was not the function of the Institution of Mechanical Engineers, and I was rightly told that they were a technical body. You, gentlemen, are a practical body (hear, hear), and it is your

business to stand up where they have failed, and to promote our industries and prepare our works in such a way that they will be able to stand in the forefront of international engineering competition. I have listened with the very greatest possible interest to the remarks of the various speakers to-night, but I am going to have the audacity to differ in one or two matters from what Sir Herbert Austin has so ably put before us. I do so, however, not as a destructive critic, but, I hope, as a constructive critic. We have been speaking of the conditions of our workers here and why it is that we are unable to meet foreign competition. I venture to suggest that the fault does not lie with the workers. I have had a very wide practical experience, and I have had the privilege of seeing many organisations in this country and elsewhere, and I unhesitatingly say that the British worker is the finest working engineer in the world. It is not his fault, and it is not his methods, that are holding us back. It is the fault of the master primarily because he is putting a limit to the developing capacity of the men. The producing capacity of the men is limited because the master does not understand the psychology of the worker. In America, the workman is entitled to earn whatever he can, and the more he earns per week the more the master is pleased, because the American master has realised that the greatest factor in the cost system is the factor of overhead charges or on-costs, which are a direct percentage of the wages paid. If your individual producer can produce twice as much, no matter what his wages are, he will at the same time reduce the on-costs per unit by one half. In England we have the very reverse. I have experienced it many, many times. You fix a piece rate price and you tell the men to go ahead, but they know perfectly well that if they earn a large wage the rate-fixer will come along and say the rate is extravagant and cut it down. That is a common practice; it is known perfectly well in all our factories, and until we can become sufficiently democratic in our works to say that a man can earn whatever he can, we shall always have this over-riding fallacy of the trades unions of keeping down production because if the men put up production they get their rate cut. I believe that the various institutions can do very useful work together. It has been suggested that joint meetings should be held, and I should like to give to the members of your Institution an open invitation to come to all the meetings of the Institution of Engineering Inspection, which are held at the Royal Society of Arts. I will see that the notices of these meetings are sent to your secretary in future, and we should welcome anyone who cares to come and join in our discussions. Our papers are on broad lines, somewhat on the same lines as your own, making for economy and efficiency, for when you have produced an article you will require the services of the inspector to say that the article is right. Although Sir Herbert has so aptly said that we are not popular people, we do serve a useful purpose. The one regret I have is that there are not a great many more visitors here to enjoy your hospitality. It is a great privilege to be with you to-night in this great movement, and I believe that the future of this country lies very largely with you in the development

of our engineering enterprises. Every man connected with the Institution should have the mission of helping to improve production in order to strengthen our commerce and so provide employment for our workers and our population. It is an Englishman's duty and one which should be responded to manfully by supporting the Institution of Production Engineers in its work for the improvement of the efficiency of our works and the employing capacity of our works. By working on these lines you will be proud, in a few years, of the mission you have so ably started.

The final toast was that of "The President."

MR. MAX LAWRENCE, proposing this said :—I have great pleasure in proposing the health of our new President. He will need all his health and strength to lead us; I have had some experience, and I am sure our retiring President will bear me out when I say that the post of President is no sinecure. In our new President we have a leader who is worthy of our fullest support, and I ask you to charge your glasses and drink to the health of our new President, Mr. Fisher.

MR. FISHER :—Gentlemen, it is very kind of you to receive Mr. Lawrence's toast in this way. His wishes for my health would lead me to anticipate a very strenuous time indeed, but be that as it may, I feel sure I shall find myself able to meet any ordinary calls of that kind, especially as I shall have the support of so many able Members of Council. As regards the work and progress of the Institution, I sincerely hope we shall find the coming year an even better one than those which have gone before. I have just had the assurance of our distinguished guests this evening that they are going to support us, and it will be our business to see that they carry out their promises. (Laughter.) The hour is late, and most of the ground has been most ably covered by previous speakers, so that I will not detain you further. I thank you for the good wishes you have so generously expressed.

THE

INSTITUTION OF PRODUCTION ENGINEERS.

A General Meeting of the Institution was held at the Engineers Club, W.1, on Monday, November 3rd, the President, Mr. W. L. Fisher, occupying the Chair.

The Minutes of the previous meeting were read and approved.

Mr. Bernard Brett, Director of Messrs. Brett's Patent Lifter Co., Coventry, then read a paper on "Drop Forging," which was followed by an interesting discussion.

DROP FORGING.

By BERNARD BRETT, Director of Brett's Patent Lifter Co., Ltd., Brett's Stamping Co., Ltd., and Powell Brett, Ltd., Coventry.

Finished forgings form the basis of most engineering productions. They always have done so since the earliest engineering history, but until the advent of the system of producing forgings in dies, the work entailed was laborious and slow, and success depended entirely upon the skill and physical effort of the blacksmith. Probably the greatest aid that he had at his disposal until comparatively recent times was the steam-hammer. There was also, of course, the hydraulic press, and these two machine tools practically covered the scope of the smithy equipment.

With both these appliances, the steam-hammer and the hydraulic press, the same hand forging methods were necessarily retained, but output was speeded up and better work produced. But when the drop-hammer became an essential feature of smithy equipment, progress in production was very great indeed. As an example of this I recollect at a wagon works in this country they were producing by means of steam-hammers, and hand-forging methods, brake triangles at a cost of 17s. 6d. each for labour. When these were produced by drop-forging methods, a better article resulted, and the labour cost was 1s. 6d. It is probably known to you that the operation of drop forging consists of inserting steel or other metal heated to a plastic condition between two dies. One of these dies is firmly fixed on to a massive anvil block; the other is keyed into the hammer-head or tup, which is lifted and allowed to fall. The blow delivered is purely a gravitation one, and the elementary principle of the drop hammer is probably hundreds of years old. It has been established, beyond any possibility of doubt, however, that this form of blow is ideal for causing the metal to flow readily into the impressions of the dies, which are sometimes of an intricate nature. The development, therefore, has been in the direction of applying modern research and practice to a system of production which is simplicity itself.

The field to-day for drop forging is an extensive one and is always growing; but in the early days of the industry, probably the greatest scope for the efforts of the drop forger was in the

manufacture of the bicycle. The first stamping company was established at Coventry about 1890 in the heart of the cycle industry, and during the first few years practically the whole of the articles produced were absorbed by the bicycle trade. The bicycle in those days was, of course, a very different proposition from the present-day machine. It is curious to reflect that bicycles 25 years ago consisted mainly of drop forgings, hubs, chain wheels, fork crowns, brake levers, cranks, saddle brackets, lever brackets, etc., which were all drop forged and machined afterwards. Nowadays nearly all these parts are produced from sheet metal.

But the bicycle, as I have already stated, provided the greatest scope for the industry, until shortly afterwards cars began to appear, and a still further field presented itself. The present-day motor car would be impossible without drop forgings. The requisite lightness and strength and molecular structure of the steel could not be obtained by any other method of production. The same applies probably to an even more marked degree to the aeroplane engine, so, commencing with the bicycle, drop forging now forms a substantial part of the construction of motor cars, aeroplane engines, rolling stock, agricultural machinery, and the production of finished forgings has in the last 25 years, as far as this country is concerned, been revolutionised by this industry.

So much, therefore, for the origin and immense scope of this most important branch of engineering enterprise, and I think I may now show you on the screen some specimens of work. I may add that these slides are perfectly new, and have never been shown to anybody. The stampings which are illustrated represent some of the latest achievements in the art of drop forging.

(Here are shown various specimens of work produced, including heavy automobile parts, engineering forgings, railway wheel centres, gear blanks for electric railways, etc.)

Probably one of the first things that will have occurred to you is the remarkably fine finish that is obtained in a drop forging, even when the shape is an intricate one. This is attributable to the fact that the final blows on a drop forging, when the metal is cooling and approaching a refractory condition, are of immense power. There is no class of appliance that delivers such a penetrating and efficient blow. It is an elastic, rebounding blow. There is no reactionary effect on any part of the plant as with a steam-hammer or hydraulic press. The last few blows, therefore, on a stamping have an enormous consolidating effect on the material, and at the same time produce the planished surface which is so clearly shown on the photographs.

I shall have something further to say presently in regard to

estimating the blow of a drop-hammer, when I show you some photographs of modern equipment. But the whole history of the drop forging industry is built up around the utilisation and the control of this potential and elastic gravitation blow. It is obtained to a far greater degree with British equipment than with the American type of board hammer or steam stamp, as with both these forms the anvil block must of necessity be placed on timber in order to neutralise the effect of crystallisation. The construction of the American board hammer demands this, but the net result of introducing a cushioning effect under the anvil block is that, say, a 20-cwt. board hammer does not give anything like such an efficient impact as a British drop-hammer of corresponding size, the construction of which permits of the anvil block being placed direct on to the solid concrete foundation.

But no one will deny that they make excellent drop forgings in America, and this is mainly attributable to the fact that they have built up in the course of years a system of drop forging which involves the use of multiple impression dies. Whereas it has always been the practice in this country to use dies having a single impression placed centrally in the hammer, and to aim at producing straight from the bar, the American drop forger, finding that the type of plant he had at his disposal did not enable him to make this short cut from the rough bar to the finished article, contrived multiple impression dies, by means of which the stamping is gradually brought up to finality of shape.

This system of production has much to commend it, and if multiple die stamping were applied to the British type of hammer, the system would be even more effective than with the American type, owing to the greater efficiency of blow obtained. Later on I will show you a photograph of a new type of hammer that is being specially constructed to give an efficient application of this multiple-die stamping.

I now propose to show you on the screen some very recent photographs of modern drop forging equipment. There are four main factors consisting, firstly, of the drop hammers; secondly, suitable furnaces for heating the bars or billets; thirdly, clipping presses for removing the fin or flash from the stamping; fourthly, the junction of the dies; and, finally, there is the question of the dies themselves.

With regard to the drop-hammers the modern appliance represents the development of many years. There is no class of plant that has to undergo such persistent and strenuous duty as that of a drop hammer; continuously, day in and day out, hundreds of blows are being delivered, not a pressure, as in the case of hydraulic presses, but sharp elastic blows, a great number of which impinge on to material which is almost unyielding—that is to say, when the stamping is receiving its final blows. Of neces-

sity, therefore, the structure of all parts must be very substantial. Great care must be taken in choosing the different classes of steel, and, finally, a lifter or means by which the tup is controlled, must be capable of not only lifting the hammer, but of holding it under perfect control, and also of arresting the blow at any time.

It will be readily seen that the tup of a heavy hammer creates a great shock on the lifter if it has to be suddenly arrested without delivering its blow. This happens sometimes when the stamper sees that his stamping is not properly placed. Drop-hammers are divided into two main classes; first, driven by steam or compressed air; second, by electric motor or belt power. The lifters in both cases have to perform exactly the same function, but they are obviously totally different appliances.

A number of lantern slides shown at this point illustrate the following important features in the design and application of drop forging equipment. These slides are as follows:—

(1) A battery of steam-driven drop-hammers working in a large stamping works. The overhead structure is quite independent of the stamp portion, *i.e.*, of the anvil block and guide rods, the lifters being carried on a separate steel platform supported by independent standards of structural steel. The obvious effect of this is that the shock taken by the base block is not transmitted to the mechanism of the lifters, the object being, of course, to isolate the lifters as much as possible. The ends of the guide rods fit into pockets of forged steel. These pockets, which are carried on the overhead girders, allow sufficient clearance round the end of the rods when they are inserted for the provision of wood wedges. These wood wedges are driven in hard, and hold the rods firmly in position.

(2) A view looking along the overhead gantry with the lifters in position showing the guide rod pockets already referred to. This battery is working at Messrs. Thos. Smith's Stamping Works, Ltd., Coventry, and it is a very interesting and modern equipment. There are two large batteries such as the one shown, and the whole of these hammers and several others are driven by waste heat generated by the furnaces from heating the bars.

(3) A view of one of these boiler and furnace sets, of which there are now six working, is given in fig. 1. Each boiler has a heating surface of 975 square feet, and is capable of evaporating 3,000 lb. of water per hour from the waste heat only, so that this firm have available steam supply at the rate of 18,200 lb. per hour at an average pressure of 90 lb. per square inch, all of which is obtained at no cost. In fact, although this plant is a very considerable one, there are no variations at all, excepting those I have mentioned, but an ample supply of steam is assured.

The furnace is coal-fired on the semi-gas principle. The average

temperature is about 1,300° C. in the furnace, the waste gases leaving at about 800° C. After they have passed over the tubular boiler, this is reduced to about 500° C. I may also add that for this furnace there are three doors, and about 38 cwt. of coal per day is used, and the system of generation ensures an almost smokeless effect. The water supply is automatic by means of a thermo-feed regulator, which controls a Weir pump. These boilers go on continuously during working beyond occasional oiling.

(4) A large lifter suitable for controlling a weight of hammer and die of 9 tons is shown in fig. 2. The construction of this lifter

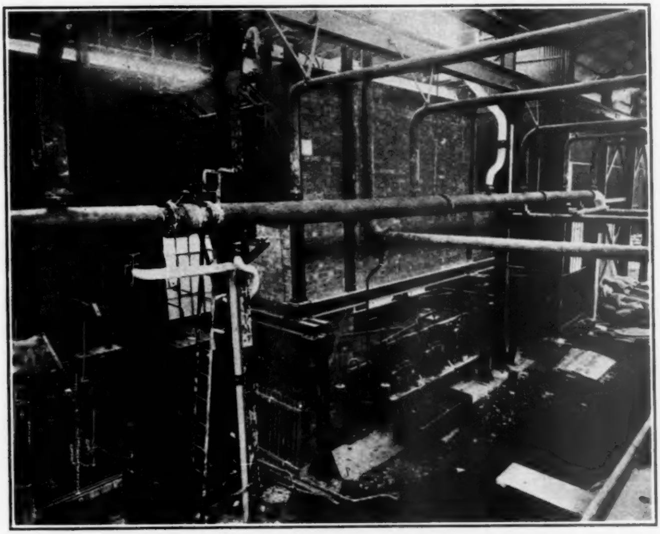


Fig. 1.—A waste heat unit and furnace set.

is very simple; the cylinder contains a wing vane which is moved round by steam. This vane is keyed into the main shaft, which, in the case of this lifter, is of very massive proportions, and on this shaft are the lifting arms, which in their circular movement pick up the hammer and control it. There are other important details of construction which time does not permit me to go into. The valve motion is on the compound system and the steam consumption is comparatively very small.

The lifters which I have already described are suitable for driving also by compressed air, and in many cases this is found to be an advantage. A very small modification to the valve motion

only is required. Of course, no one would think of installing a compressed air plant specially for driving drop hammers, as there are more economical ways of going to work, but in some works, particularly in Italy, compressed air is used to a very great extent, produced by water turbine power. In such cases it is convenient to use compressed air, which is perfectly satisfactory.

(5.) A battery of friction- or motor-driven drop hammers. The lifters are naturally of quite a different type to those on the previous batteries of hammers arranged for steam or compressed air drive, and their duty is to control the tup, deliver light or heavy blows if desired, and, in short, to perform with equal efficiency the same duty as the steam lifter which has the advan-

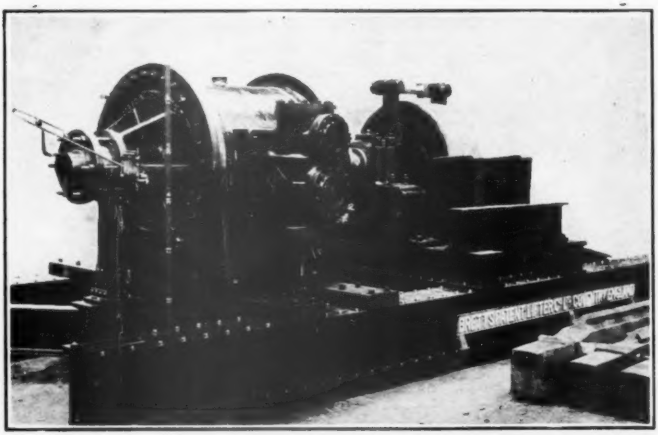


Fig. 2.—A large steam lifter.

tage of an elastic power. Friction lifters are mounted on a continuously running shaft, and the control and the working of the tup is by frictional effort. I would like to draw attention to the form of drive adopted on this battery. The motor is applied direct, and is constantly running at about 750 r.p.m. The main shaft of the lifter, in order to give proper control, rotates at about 40 r.p.m. The necessary reduction between the motor and the shaft is carried out by the double reduction gear box shown. This consists of a double train of machine-cut helical gears running in an oil bath which is very silent and efficient in action. The motor is connected to the high-speed end of this gear box by means of a centrifugal expanding clutch, which permits of the motor being started up without load, power

being gradually transmitted as the speed increases. This clutch also possesses a considerable amount of elasticity: that is to say, it will slip a little in the case of undue shock.

(6.) One of the friction lifters mounted on the battery previously mentioned is shown in fig. 3. This is really a very powerful form of friction clutch, and as I have already explained, the duty it has to perform is a most strenuous one.

The working is as follows:—

A steel drum is firmly keyed on to the main shaft, and this is fitted with multiple grooves, V shape. Into each of these grooves, the number of which varies according to the size of the hammer, are fitted the friction blocks shown. These friction blocks are

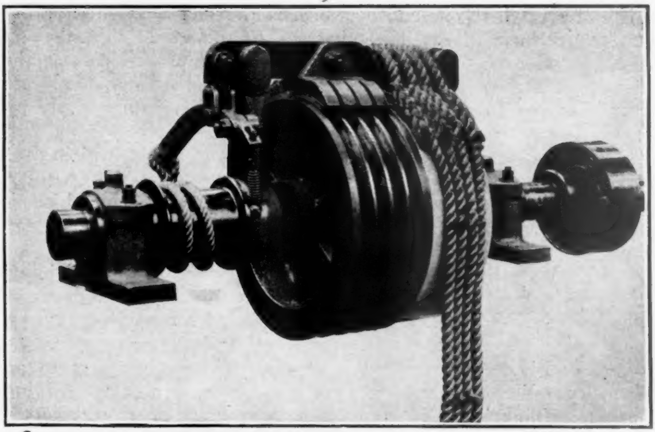


Fig. 3.—A typical friction lifter.

faced with a special ferobestos material, which can readily be replaced when worn. At the side of the grooved steel drum is an ordinary loose pulley, which takes the weight of the hammer suspended to the lifting belt. Outside the pulleys are the two steel lifting arms, which are drop forgings. They are bushed with phosphor bronze, and free to rotate on the shaft. Connecting these two arms is a steel shackle, on which is flexibly mounted the shoe carrying the friction blocks. This shackle is hinged at one end, but it moves between the jaws of the opposite lifting lever. Normally this shackle is in such a position that the friction blocks are quite free of the grooves, but when the operator pulls the handle the control lever moves downwards. This motion is followed by the shackle to which it is connected, and the friction

blocks are applied with the necessary pressure. The simplicity of this mechanism must commend itself to you, although it is the result of many years' development, simple as it looks.

(7.) A lifter mounted on the steel chassis with the buffers, etc. This lifter has only one friction block, and it is for quite a small hammer. With regard to the actual working of the hammer, the cord first of all coils round the winch, and as soon as this tightens, the control lever puts the gear in action. There is very great sympathy between the touch of the driver's hand and the hammer head which he controls. A very light touch will lift the hammer, and the operator's hand only moves a few inches in giving a full stroke. There is another contrivance here to which I should like to draw your attention, and that is the release cord. This consists of a cord, to one end of which is attached a weight working up and down a tube. The other end of this cord is attached to the control rope, and as soon as the pressure is taken off the handle, the rope is immediately uncoiled which totally eliminates any tendency to drag. Also the hammer falls with a perfectly free effect giving its full blow.

(8.) Another view of the head of a friction lifter, which gives another form of drive to that which I have already mentioned. Instead of a gear box there is simply a flywheel to which is attached the belt from the motor, and the reduction is obtained by means of a single train of machine-cut gears.

(9.) A small hammer of an interesting type. The weight of the tup is 5 cwt., and the hammer is quite self-contained. A number of these hammers have been supplied for small work such as shaping magneto magnets, spoon and fork stamping, etc.

(10.) Fig. 4 shows the application of drop hammers to an industry quite outside that of the ordinary hot drop forging process. This is really part of a large equipment supplied to Messrs. Mappin & Webb's new works at Sheffield. It is probably recognised that in the silversmiths' trade the hammers used are of a very antiquated design, and until this plant had been installed no attempt had apparently been made to create a really efficient silversmith's hammer. However, Messrs. Mappin & Webb are very enterprising people, and we had an opportunity of applying the development that has taken place with drop hammers to the silversmith's trade, and this has been done with very great advantage. The lifters are of the friction-driven type, driven by motors applied direct, through enclosed type gear boxes. Each man drives his own hammer, and turns out very large work. The weight of the tup in this case is 20 cwts. The design of the stamp portion of the hammer is somewhat different to that used in the drop forging industry, and for this we are indebted very much to Messrs. Mappin & Webb, who were kind enough to give us full information as to the type of stamp, *i.e.*, particulars of

the anvil blocks and the guide rods which their men prefer. However, there are some 20 of these hammers working and producing vast numbers of spoons and forks, dishes and all classes of silversmiths' work.

While I am on the question of plant I should like to refer to the subject of multiple die stamping, and also to the design of hammer which has been specially brought out for the successful application of this system of drop forging.

In the usual type of British drop hammer, it has always been the practice in the drop forging industry, where tremendous

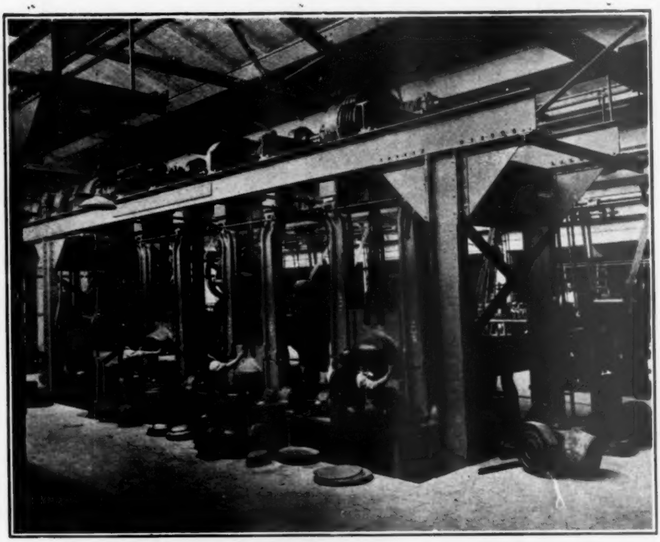


Fig. 4.—Modern motor-driven drop-hammers for silversmith's work.

numbers of this type of equipment are in operation, to have a single impression in the die, because firstly it was the practice to produce straight from the bar, and secondly it will be obvious that if the hammer impinges on the plastic metal quite centrally, there is little or no shock on the guide rods. If, on the other hand, the hammer descends on to a stamping placed on one side of the hammer, out of centre, then a tilting effect is created, and guide rods have been broken or bent owing to this happening. As the application of multiple die stamping involves at least three impressions in the die, it is obvious that they cannot be put into successful operation without this side shock being created. It is

thus unsafe to attempt successful multiple die stamping with the class of plant hitherto constructed. Owing to the fact that the construction of the lower part of the hammer is not sufficiently strong to withstand the enormous side shock set up, this is

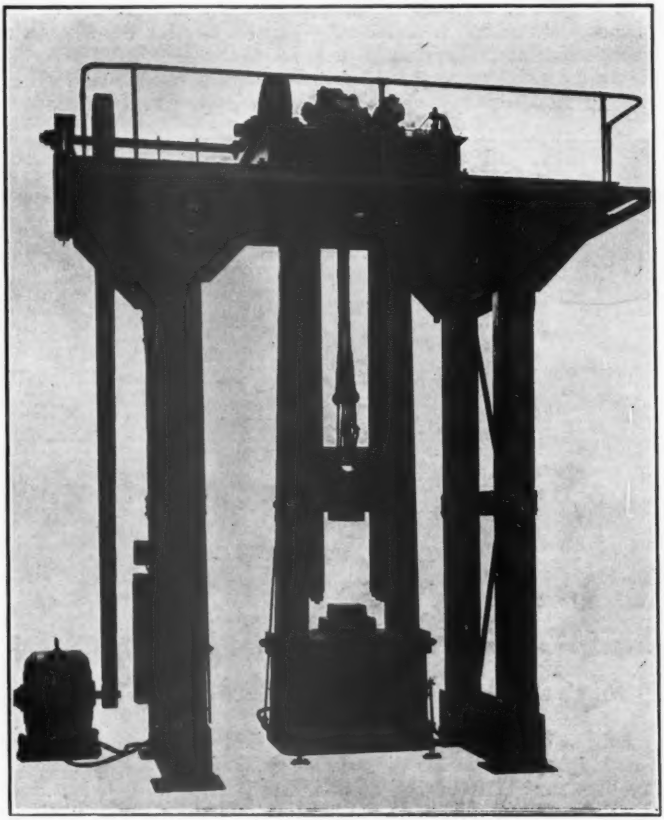


Fig. 5.—A hammer designed for multiple stamping.

guarded against in American hammers by using exceedingly massive steel rods.

(11 and 12.) The type of hammer designed for multiple die stamping is shown in fig. 5. It is friction driven, and the only

variation from the standard practice is in connection with the guide rods and base block. Instead of the usual column of iron or steel fixed at one end, and fitted into a recess in the anvil block, the guide rods are compound and consist of a combination of rolled steel girders and steel segments. The steel girders are firmly fixed in position top and bottom, and this position is permanent, but obviously adjustment is required, and this adjustment for multiple die stamping must be of a very accurate nature. Fitted on the inside of these girders and working on machined faces are two steel segments. The main supports are set at a permanent angle sloping slightly inwards towards one another at the top, and the corresponding faces of the sliding strips are tapered so that their inward edges are always parallel with each other no matter what their vertical positions may be. The height of these sliding strips is adjusted by means of a worm and wheel, and they are secured in the desired position by means of bolts and nuts, the former passing through elongated holes. It will be seen, therefore, that in addition to remaining parallel the inwardly facing edges of the sliding strips close in towards one another, or are separated from one another according to whether they are raised or lowered. An exceedingly accurate slide fit is, therefore, assured, and any tendency to tilt when the hammer meets a resistance that is not central, as in the case of multiple die stamping, is prevented. In other words, this combination of permanent steel structure with the sliding segments gives the most powerful form of support to the tup, and also a very delicate adjustment, so that multiple die stamping can be applied efficiently and with perfect safety.

The base block of this hammer is placed direct on to the solid concrete so that the maximum efficiency of impact is obtained, in contradistinction to the American hammer, which has a bed of wood underneath the anvil block creating a cushioning effect.

(13.) Fig. 6 shows the largest drop hammer ever constructed. It has been installed for the purpose of producing very heavy work, such as rolling stock wheel centres, heavy gear blanks, etc., specimens of which you have already seen. The hammer is 20-ton capacity, and it is a very formidable piece of plant, as will be seen. The anvil block is built up of forged steel, each section dovetailed into the other, and it is placed direct on to a very large concrete foundation. This hammer is driven by the waste heat of the furnaces; power is thus derived at no cost. It is designed to be capable of taking a die up to 6 ft. in diameter, which of course is a very large size. I mentioned a little time back that I would say something about the force of blow of a drop hammer, and I am indebted to Mr. Lough Pendred, the Editor of the *Engineer*, for some interesting figures which he published recently regarding this hammer. He remarks as follows:

"As a matter of interest we have made a rather rough calculation as to the force of blow delivered by this huge stamp with its weight of 20 tons falling through 10 ft. It we may assume that the penetration (*i.e.*, reduction in the size of the plastic steel under

Fig. 6.—The largest drop hammer ever built.

concussion) amounts to $\frac{3}{8}$ in., then the blow exerted, or what is sometimes called the pressure of the blow, is no less than 6,400 tons. If, as may well happen when the metal gets denser and harder, the depth of impression is reduced, let us say, to $\frac{1}{32}$in.,

then the pressure of the blow becomes 12 times as great and amounts to no less than 76,800 tons."

This, of course, is a colossal impact, and no one would realise that such blows are being exerted on the metal when these big stampings are being produced. There is no undue shock.

We now come to the question of furnaces, which are a most important part of a drop forging equipment. There are three main classes, viz., those fired by coal, oil and coke.

(14.) A coal-fired furnace, which is actually the type of furnace we generally fit in a boiler so that the waste heat is utilised. The coal is fired into a separate chamber which is constructed on the semi-gas principle. The temperature obtained is about 1,300° C.

(15.) An oil-fired furnace. Oil is a very satisfactory fuel for drop forging purposes; the only drawback is that the price of the fuel is a somewhat variable quantity. The burner shown at the end converts the oil into a gas. The apparatus embodies a valve which takes the form of a tube which is machined to a sharp edge. Working against this tube is a disc through which the oil sprays in a thin stream. A rapidly rotating aluminium propellor effectively sprays the oil, which then passes into a combustion chamber, and finally into the furnace. A very clean, smokeless and soaking heat is obtained, and a temperature up to 1,400° C. is readily possible. One of the advantages of an oil furnace is that the billets are heated very rapidly, resulting in an increased output.

(16.) A standard type of coke fired furnace. The fuel is simply fed into the hoppers shown on either side, and a place is provided underneath for a fan or Rootes blower. A coke furnace is a very reliable and satisfactory appliance, and great numbers are in use. They are not so free from sulphur as oil or coal, but a uniform heat is obtained, and satisfactory work is generally produced.

We now come to the question of the clipping presses which are used for removing the fin or flash from the stampings as they leave the dies.

(17.) A favourite form of press of the overhanging type. This press is motor driven, and it has two distinct slides, which are separately operated by means of a foot treadle. The motion is a very simple contrivance, and consists of a bolt working in and out of the flywheel, which engages the side of a disc, thus putting the slide into motion. The operation of clipping a stamping is a single one; that is to say, it is quite distinct from such a process as drawing out sheet metal blanks, for which a prolonged pressure is required. A heavy flywheel really contains sufficient inertia to do the work, and gearing is generally unnecessary.

(18.) Another type of press which is fitted with side shears for

cutting off the stamping from the bar. The motion is identically the same as that on the previous machine. The general design of this machine is preferable for some classes of work, whilst the overhanging form is more suitable for long stampings, as they can be more readily inserted underneath the slide.

Finally we come to the question of dies, of which a great deal can be said; but time does not permit going into the question except very briefly. Dies should be made of a high carbon steel, and in some cases an alloy steel is used. But the blocks are forgings, and the impression is cut from the solid by means of machine tools of various sorts, mainly milling machines, and finally the impression is carefully scraped and filed by hand.

(19.) A group of dies for railway work. The articles being produced are such parts as drawbar hooks and drawbar plates, and similar work. These are not hardened, but the forgings are frequently normalised before the impression is cut. It is found, however, that dies of reasonable size are better left unhardened, because firstly it is difficult to get a uniform effect, and secondly, it is undoubtedly correct to state that in actual service the skin of the impression automatically hardens itself.

THE DISCUSSION.

MR. BUTLER (Kirkstall Forge): I thank Mr. Brett for his kindly remarks about myself. I am sorry to say that I have been out of touch now with the active part of the business for some years, and cannot give any tips regarding stamping. There are one or two questions I should like to ask. I have often wondered why in the United States, as far as I know, they use nothing else but the steam stamp and the board stamp. One of my nephews came back from the States full of the advantages the American steam stamp had over the Brett stamp. My defence of the Brett stamp to some of our staff was that I thought the reason why the American stamp had been so successful was because the Americans have such enormous quantities to make of the same pattern. Given a sufficiently large order of one particular stamping, I believe the Brett stamp would equal the American type for output. Of course, the American stamp has the advantage that it works much more quickly; with the stamp at top and bottom it strikes many more blows than the Brett stamp—perhaps four cr five times as many—in the same time. It is now fifty years since I remember going to the Continent and visiting several works where they used the Haswell hydraulic press. I saw them pressing connecting rod ends at such speed that the surplus metal out of the die squirted out, although it was in iron, not in steel. It seems strange to me that that process has not been persevered with. It was quite an extraordinary process, although the finished work was rather rough. Then I should like Mr. Brett to tell us how it is that the 20-ton installation that he spoke of generates a force of 6,000 tons under certain circumstances, while under other circumstances the effect of the blow is equal to 70,000 tons. I should have thought the effect of the blow with a drop of 10ft. would be the same whether the metal to be stamped was an inch thick or three-sixteenths of an inch thick. Another thing in America which greatly impressed our staff was the multiple-die system. The American stamps are constructed somewhat on the lines of the designs Mr. Brett has shown us, having loose slides bolted to the uprights, but there must be enormous wear and tear. Of course, the quantity of the work they do is very great. In this country our experience is that we have to sink dies and submit a sample, and then the order comes for perhaps fifty, although people may dangle before us the prospect of ordering a few hundred later on! That has been our disadvantage in the stamping trade—the small quantities that people order. This Institution should use its influence in obtaining standardisation beyond what we have already. In the early days of the motor industry every motor firm used to bring out new models every year, and we never had more than one year's run of one set of dies, and the cost of those dies was appalling. With regard to the old hammer that

Mr. Brett mentioned as having seen at work at the Kirkstall Forge, it consisted of a rotating cam lifting a large cast-iron helve, which dropped, falling about 18in.; it weighed about two tons. It is interesting to learn how Nasmyth came to invent his hammer. Actually the first steam hammer, I believe, was made by Schneider in France. Schneider called at Nasmyth's works, saw the plans, and went back to France and made the first hammer there. I should like to add that I am sure we are all very much indebted to Mr. Brett for his interesting lecture. It is only the latest addition to our obligation to the Brett family and firm for all that they have done to give us the means of founding such a wonderful industry.

Mr. Wheeler: I should like to know how the forces—that is, the male portion of the die—are made. Are they made of steel to correspond with the die?

Mr. Brett: The first thing that Mr. Butler asked was why the Americans had not adopted Brett hammers. Well, the reply is that they have not been particularly asked to do so. We have never pushed the supply in America. But an eminent drop forger, a great man in the American stamping world, admitted while walking round a works at Coventry—we were looking at a connecting rod being made straight from a square billet, and it was drop-forged, stamped, and clipped and put down in one minute twenty seconds—"If I had a hammer that would do that in America I would make it do five times the work." What he meant was that he would take that potential blow of a British drop hammer, which is indisputably and abundantly established, and apply to it a system they have in the States—a system of multiple-die production. The method is the outcome of many years of development, and, as I mentioned, arose from the inherent weakness in the board hammer and the steam stamp, which has a lot of depreciation. It is quite true to say that steam stamps have in one or two cases been installed in this country; they are somewhat spectacular, but when carefully investigated the only spectacular aspect arises from the fact that a steam stamp is put to produce drop forgings very much below its actual capacity. It is true to say that a steam stamp, owing to the fact that its blow is undoubtedly accelerated by steam, as against the fact that a drop hammer falls entirely by its own weight, results in quicker blows. But the blows of a steam stamp are striking an anvil block that is cushioned. They are impinging on a block that is set in a body of timber, so that although the blows are more rapid they are much lessened in efficiency. A 20-cwt. steam stamp does not give as efficient a blow as a 20-cwt. drop hammer falling by gravity, in spite of the disproportionate quantity of steam that it uses. I agree with the multiple impression die system, and I think that it is a system that should be introduced into this country for drop forging purposes. But it could not be employed with safety with the class of drop hammer that has been made in the past. In order to render the application of multiple die stamping satisfactory in this country, the drop hammer must possess the strength and accuracy of adjustment which, I endeavoured to show you, was possessed by the hammer shown on the screen. Mr. Butler asked me to explain the reason for the variation in the blow of the big hammer from 6,400 tons in the

one case to 76,800 tons in the other. The whole question of the force of impact depends on the length of time in which a blow is absorbed. If the hammer descends on to a mass that immediately yields under the impact to the extent of $\frac{3}{8}$in., so that the blow is to that extent absorbed, the net impact, obviously, is much less than the apparent impact; but when the metal is in such a condition as to be unyielding or refractory or nearly so, so that the actual penetration is very small—say, $\frac{1}{32}$in.—then the efficiency of the impact, or the net impact, is multiplied by twelve. Mr. Butler mentioned a hydraulic press he saw working on the Continent. I can point to the whole history of the drop-forging industry to establish the fact that there is no class of appliance that has the extraordinary flowing effect on metal that a gravitation blow has. A hydraulic press, on the other hand, is a dead squeeze. The hydraulic press and the steam hammer were in existence before the modern drop hammer, but I think everybody would admit that for multiple die forging and for multiple production and finished forgings there is nothing to-day to touch the drop hammer. But I do want to make this point perfectly clear. We must be prepared to learn something, and if I were addressing a meeting of drop forgers I should say that we must learn something from America. We must try to combine their wonderful system of multiple die manufacture with the British drop hammer, and I am perfectly sure that we shall then be ahead of the Americans.

In answer to Mr. Wheeler, the dies are really cut from the solid; they are machined and milled, and then put into operation. The use of the force depends, of course, on the finished stamping that has to be made, but in standard British practice the object is not to attempt to produce anything like a finished shape. The die itself is left to finish the job, and we merely rough out the bar to a very small extent. Of course, with multiple die stamping—having three impressions in the die—no roughing is done. The heated billet is placed on one side of the die, and then on the opposite side of the die, which still further shapes it, and finally in the centre of the die to finish it.

Mr. Bass (Member): What is the method of holding the larger-sized dies?

Mr. Brett: The die in the hammer head is held by a dovetail. The lower die can be held in two ways: it can be held in a dovetail like the other, but that is not much favoured by British drop forgers, and generally in this country it is held by poppets. I omitted to deal just now with a point made by Mr. Butler with regard to the American drop forgers. I quite agree with him that the drop forgers in this country do not specialise sufficiently. We do not find drop forging firms in America laying themselves out to do fifties or hundreds. They are not prepared to go to their stamper and ask him to make two hundred drop bar hooks one day, and after he has finished that to make something entirely different. The drop forger in America keeps to one job, and thus arrives at a state of efficiency we cannot hope to reach in this country. The only solution would be for the drop forging industry to be organised, but I think Mr. Butler would probably tell us that that would be a very difficult proposition.

Mr. Butler (Kirkstall Forge): It is the engineers who want organising.

The President: Would not the upward flow of which Mr. Brett spoke be what one would anticipate—not quite so mysterious as he appeared to suggest?

Mr. Brett: I do not think the question has ever been satisfactorily explained. The reaction of a blow must coincide with the action, it is true, but I think there is some drawing, inducing, or sucking effect to be accounted for.

The President: The reaction would follow the action with a certain lag.

Mr. Brett: It is very slight. It belongs to that same point which I made about the difference between the dead blow of the steam hammer and the gravitational blow, and the fact that one gets the maximum effect in the gravitational blow. I think the reason is all wrapped up in the interaction between the two masses.

Mr. Bass (Member): Mr. Brett mentioned that it was impossible to heat-treat some of the large dies. I believe that some of our metallurgists would contest such a statement. It is a matter of selecting the right material from which to make the dies. I have known very large plates heat-treated, and after heat-treatment they have been finished and have not moved from their original form. Mr. Brett also referred to the flashing. A flash seems to suggest an excess of material. Why could a calculation not be made whereby there would be sufficient material to fill the dies, having the correct form, but stopping short of the point at which a flash is induced?

Mr. Brett: The stamper has his raw material—a bar—and out of this bar he has to rough out his metal in such a way as to provide the bulk of material necessary to fill the particular part of the die, which varies, of course, in size. It is frequently an axiom in the trade that it is cheaper to make excessive scrap than to spend time in carefully working out the stamping size. To do this means such great care in the roughing out that it is greater economy to waste the metal. I did not say that it was impossible to heat-treat big dies; I said it was inexpedient. A big die is an expensive thing to heat-treat, and actual practice shows that heat-treating does not help much. It is impossible to get an equal thickness of hardening effect in the die. The hardened face does not penetrate equally, and under the action of stamping the top face is hammered into the lower face and distortion is produced. But I agree that for alloy steels when used for die purposes it is advisable to heat-treat the dies before cutting the impression, though not afterwards.

Mr. Zieshang: What are the advantages of rolling as against drop stamping when handling small articles such as scissors or surgical instruments? Such parts do not appear to be quite the proper thing for drop stamping, and I know that rolling is employed successfully. Take such a thing as a sword-blade, for instance; a drop stamp would be hopeless, and this applies to all thin components. For a big crankshaft or anything bulky the die will last indefinitely, but the method of rolling for small articles is a thing which, I think, should be studied in this country. One result of this method is that

in Germany or Belgium, where it is practised, a gross of scissors can be bought for the price of a dozen here.

Mr. Brett: I am most interested to hear what Mr. Zieshang has said, and I shall be very glad to have further information. About fifteen years ago, in Belgium, I heard that they were rolling certain articles. But, of course, one cannot perform miracles. It is not possible to perform the operation of filling a die with plastic metal properly by means of a steady squeeze. It may be possible with very plain articles to roll them. I have thought of it myself, but I am always willing to learn. I have in mind an industry where a number of hammers were supplied for making needles, and they are still working; they are doing the eyes of the needles—very heavy needles. The people concerned investigated several methods of manufacture, and drop hammers were found to be the most efficient.

Mr. Zieshang: Take surgical instruments; these lend themselves beautifully to rolling, and there is an enormous demand for them. By rolling it is possible to do what we have always been trying to do by drop stamping.

Mr. Brett: I suppose you place the impression parallel to the axis of the rolls?

Mr. Zieshang: A series of impressions is made along the rolls, and the die is sunk in the curve. The article comes out dead straight. I shall be pleased to send details to the lecturer.

Mr. Gerrard Smith: I speak as a man no longer in the shop, but I am thinking rather of the drop stamper in relation to the office equipment trade where small stampings are required. We take a body of sheet steel, make a tool, bend the piece of steel, turn up a boss—in fact, we go through five or six operations in order to get one small thing, and we have to do it in hundreds. I am convinced that if the drop-stamping trade would try and develop on this small line an enormous field would be opened up. The temptation has hitherto been to see how big they can go. But consider an instrument which has a large number of small parts, many of which are cast-iron or brass, many of them breakable; heavier than they need to be for stamping. I required some pins, $\frac{5}{16}$in., with a boss $\frac{5}{8}$in. in diameter, but when the consignment came in I had to return the whole lot, because in half of them the dies had not come down on top of one another. I suggest that if this trade were looked into and really fine finished forgings were produced, a very wide field would be opened up. Whether it is possible to avoid scale by using stainless steel or iron I do not know, but if so one would expect to obtain an article which could be enamelled or even plated straight away rather than the rough scaly finish to which we are accustomed.

Mr. Brett: I much appreciate the caution that we may be thinking too much of big things and neglecting little things. If the speaker could send me some specimens of these small articles I should be very glad to investigate the matter. I am perfectly sure that small drop forgings can be made with the greatest accuracy.

Mr. Butler (Member of Council): I should like Mr. Brett to give us some idea of the time taken to produce the very heavy stampings; also the number of times they have to be heated.

I have had considerable trouble with small stampings owing to

the top and bottom tools not being in proper register. Would it not be possible in the case of small hammers to use some form of guide or dowel pins accurately to locate the dies? Several instances could be quoted where stampings have been abandoned in favour of malleable castings, owing to the difficulty and expense of trimming up badly made stampings.

I should also like Mr. Brett to tell us the limit of weight of hammer for satisfactory work with an ordinary flat belt friction lifter. I have used this type with hammers weighing up to half a ton, but chiefly on sheet metal work, where the die was in cast-iron and the top tool antimonial lead or gun-metal.

Mr. Brett: The actual time of stamping in one of these centres is two minutes. With regard to the question asked about belt hammers, my reply is: Why use old-fashioned belt hammers when you have twenty-five years' collective experience in the construction of drop-forging equipment? There is no doubt that even for half a hundredweight an automatic lifter should be fitted on. Everything depends on the physical effort of the worker, and the smaller the amount of physical effort put on to him, the longer he can work. I agree that, for some reason or other, many drop forgers do not feel that it is necessary to work accurately for small stampings. The drop forgers must be prepared to give accurate work in the case of these small articles, and when the need is brought home to them I think that they will do so very well.

Mr. Hutchinson: The value of the drop forging to the production engineer is very great. But, in the same way, the value of the production engineer to the drop forger is equally great, because he makes the field for the drop forger's work. I recall one rather interesting case of a component having a large boss, where the machining time worked out at something like 700 hours for a forging. Using a drop stamping, this was reduced to just a fraction over 100 hours. That will give some idea of what drop forging can do for the production engineer. The matter of rolling has also been mentioned. Before the war I used to make a large number of small stampings, and after trimming them to weight, re-heating and putting through a second die for sizing, I was able to produce small stampings to within very close limits. It was a very profitable line, although I dealt only with small stampings up to four ounces, but I believe the Germans to-day are working on similar lines for larger stampings. The result is a considerable saving in machining costs, and I think that we in this country should try to keep pace with improvements of this kind. I should like to have heard from Mr. Brett something about the avoidance of cracks in forgings. By more careful consideration of otherwise unimportant features in the design of stampings I am confident that the number of cracks might easily be minimised. With regard to the flow of the metal upwards it seems to me that the inertia of the billet may be important. In striking a fairly weighty piece of steel at a high speed, it is only natural that the weight of the billet itself should rather resist the downward motion, and it would take very little to change the flow from a downward to upward direction. Regarding multiple dies it appears that the direction of grain in the metal might be

controlled very much better than by simply leaving it to the man to get his forging out in the quickest possible way, very often to the detriment of the forging itself. Mr. Brett said that heat-treatment was principally to overcome faults in stamping. The correct heat-treatment of a stamping, to my mind, adds materially to its subsequent utility, especially in highly stressed parts. The stamping of pins has been mentioned, but this is hardly a job for the drop stamper. Other methods are simpler and more efficient. With reference to standardisation, that is a matter upon which this Institution hopes, as time goes on, to bring considerable influence to bear. Greater standardisation is undoubtedly one of the things we do want. If we could reach the same pitch of standardisation as the Americans have done many of our difficulties would vanish.

I should like, in the name of all present, to express our very hearty thanks to Mr. Brett for his lecture, and I venture to hope we shall have the pleasure of seeing him again.

The informal vote of thanks was carried with hearty acclamation.

Mr. Brett: I much appreciate Mr. Hutchinson's kind words, and your endorsement of them. I must correct, however, one misapprehension in his remarks. I could not have said anything to belittle the extraordinary advantages that accrue from heat-treatment. Heat-treatment is practised not to get rid of flaws: it is to correct a wrong steel structure, and as a means of releasing stresses that may be set up in certain intricate stampings heat-treatment has proved to be one of the most beneficial processes in the hands of the drop forger. With regard to cracks, surely it is a most exceptional thing to get a crack in a stamping. The only stamping in which a crack may possibly have been discovered is a crankshaft made from a slab—a crack that cannot be detected, but it is there.

There is one point on which none of us has touched this evening. The successful achievement of the drop forger and of the production engineer lies in the hands of the workman. I cannot refrain to-night from saying that all of us who are responsible as employers of men, must in the future, whether we have done it in the past or not, enlist to the greatest possible extent their co-operation by making them feel that their employers have their interests at heart. The return of a Conservative Government to power with an overwhelming majority carries with it an added responsibility upon employers to consider the interests of the workers, and all in a position to do so should endeavour to the greatest possible extent to carry their workpeople along with them in their commercial enterprises. (Hear, hear.)

I am very glad to have been here to-night and to know that my lecture, brief as it was, has led to such an excellent discussion.

THE

INSTITUTION OF PRODUCTION ENGINEERS.

A General Meeting of the Institution was held at the Engineers' Club, Coventry Street, London, W.1, on Friday, November 21st, the President, Mr. W. L. Fisher, being in the Chair.

The Minutes of the previous meeting were read and approved.

Mr. O. H. Medcalfe, of the Power Plant Co., West Drayton, Middlesex, then read a paper on "Gear Shaping, with Special Reference to the 'Sykes' Generating System," which was followed by an interesting discussion in which both visitors and members took part.

GEAR SHAPING, WITH PARTICULAR REFERENCE TO THE "SYKES" GENERATING SYSTEM.

By Mr. O. H. MEDCALFE, of the Power Plant Co., Ltd., West Drayton, Middlesex.

A discussion on gear shapers must necessarily be prefaced by a consideration of the gears to be cut and the tooth shapes the machines will be called upon to produce. The types of gearing which will claim our attention principally are straight spur, single, double helical, and internal gears connecting parallel shafts.

The tooth-shape that is now universally adopted is that known as the "involute." The advantages of the "involute" curve applied to gear teeth are well known, and its properties will be dealt with more fully when considering the pinion type of cutters as used on the Fellows and Sykes gear generators.

The advent of modern gear cutting machinery has made it possible to produce this "involute" type of profile with great precision and economy, with the result that it is rapidly displacing the earlier methods of production by a milling process using sets of cutters each one of which can only be truly accurate for one given number of teeth.

Various methods have been proposed and used at different times for the production of gears, which, whilst being in themselves models of ingenuity, lack the essentials which go to make the process a generating one. I therefore propose to deal only with generating methods as being representative of modern practice.

The gear generators on the market to-day can be divided into three classes.

1. Those using cutters of rack formation.
2. Those employing pinion-shaped cutters.
3. Those using hobs.

Of the first-named class, the Sunderland gear cutting machine is the prototype; the Muir, Maag, and others have adopted this principle with slight mechanical variations.

Of the second-named class, the Fellows and the Sykes gear generators are the most widely known, and of these two machines, as will be shown later, the Sykes machine has been specially developed for the production of double helical gears with continuous teeth cut from a solid blank.

With reference to those machines using cutters of rack formation, they represent the only alternative to cutters of the pinion type for the shaping or planing process; but as the Sunderland machine necessitates the withdrawal of the rack cutter from the gear being cut at every pitch or at least every two pitches, a certain amount of time is lost and the number of moving parts increased to obtain this motion of withdrawal and return. This in itself militates against accuracy.

The Muir vertical gear generator is designed to obviate the loss of time incurred in returning the rack cutter to its commencing position. This is done by a rapid movement in between the cutting strokes, but the objection of additional moving parts still remains.

Considering machines using pinion cutters :—

The Fellows gear generating machine is well known as the first successful gear shaping machine to be generally used in this country. Using a single pinion cutter, it is undoubtedly a very efficient machine for its capacity, and can produce gears of a high standard of accuracy.

The cutter is mounted on a ram which is attached to a straight guide to which is imparted simultaneously a reciprocating and a rotary motion. It should be noted that the return stroke is an idle one.

By changing the straight guide and replacing it with a helical one, a helical cutter can be used for producing single helical gears. It must be understood, however, that a right-hand guide and cutter will produce a right-hand single helical gear; therefore, for a left-hand single helical gear, a left-handed guide and cutter must be used.

The Sykes gear generating machine is undoubtedly the result of a close study of gear cutting as presented by pinion type gear shapers. No claim for the cutters is made on the basis of novelty, but immense improvements in their application are justly claimed.

Before the development of the Sykes machine, the great advantages of double helical gearing with continuous teeth, such as the elimination of side thrust, narrower face widths, and consequently shorter shafts, had been visualised. Indeed, some steps in that direction had already been taken by cutting two single helical rims with right- and left-hand helices respectively and pinning them together. The risk of their movement in relation to each other under severe stress, however, was always a danger, also the cost of manufacture was naturally high.

The problem, therefore, confronting the inventor of the Sykes machine was to incorporate a second cutter acting in unison with the first in such a manner as to produce a perfectly continuous double helical tooth bearing its share of tooth pressure right up to the apex of the tooth.

Each cutter must have a true generating or moulding action with the gear being cut, and a reciprocating motion across the face of the work, but differing from the action of the spur gear cutter, in that a helical or twisting movement must also be imparted. The cutters must be capable of adjustment axially with respect to each other.

These various movements must all be derived from one common source, which has to be accurate in its transmission, so that three distinct motions are obtained in perfect synchronism; these motions as referred to above are: reciprocating the cutter across the face of the blank, a twisting motion to give the desired helical trace, and a rotary motion of blank and cutter in unison.

In the first machine built to fulfil these conditions, two cutters were mounted horizontally on cutter brackets, each on a separate sliding carriage, actuated by a common drive, the helical movement being obtained by rifled bars. It was found that this design did not make for accessibility or admit of a wide range of work.

From the experience gained, however, an improved type of machine was designed in which both cutters were mounted on one sliding carriage, the drive and the helical movements being located at one end of the machine. A further improvement was made whereby the cutters were withdrawn from the work on the non-cutting stroke, a matter of great importance in the life of the cutters.

From the very favourable result obtained with the later machine, a range of Sykes machines has been designed, and it is proposed now to describe in detail their actual design and manner of construction. Before doing so, it should also be stated that cutter design and production, without which the machines themselves would be useless, were developed concurrently. This may be dealt with after the detailed consideration of the machines has taken place.

Commencing with the Sykes No. 2 machine, this machine is designed to cut double helical straight spur and internal gears, and has a capacity from ½in. diameter to 24in. diameter; face width, 12in. double helical face. The helical angle of teeth decided upon as fulfilling all conditions in a satisfactory manner is 30°.

This is a fixed quantity, meaning that whatever the diameter of gear being cut, the angle of inclination of teeth across the face will be 30°. It can be varied between 25° and 35° by using larger or smaller cutters, further variations necessitating new guides.

Dealing first with the reciprocating motion of the cutters, the main cone pulley is driven from a counter-shaft running at 500 r.p.m. The cone pulley speeds range from 330 to 750 r.p.m., the pulley being mounted on a shaft which carries a worm gearing

with a 10 : 1 reduction worm wheel which drives a disc crank. The worm shaft is mounted in ball bearings, and the end thrust is also taken by a double ball thrust washer.

The crank disc is fitted with a crank pin which is adjustable for stroke, and this is coupled to the large slide mounted in front of the cutter bed. This slide carries the two cutter heads on which are mounted the cutters. The two heads are adjustable on the main slide by means of screws passing through it.

Each cutter head is provided with a slanting face, corresponding to a similar face on the cutter head base, and on which it has a small movement endwise. The resulting action when at work is

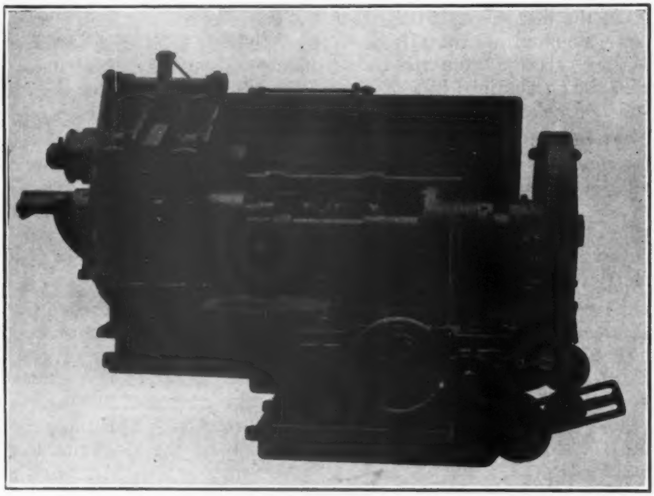


Fig. 1.—The No. 2 "Sykes" gear generating machine.

that the main slide in reciprocating carries the cutter head bases rigidly with it, but the cutter heads do not respond to the movement until the small endwise space has been taken up. Due to this small relative movement between the cutter heads and their bases, the cutters are withdrawn from the work at the end of each cutting stroke and restored at the commencement of the cutting stroke.

The endwise movement is determined by positive stops, and it should be said that the true alignment of bores is secured when machining by setting up the slide with the cutter heads in position on the boring machine and finishing the bores to very fine limits.

This reciprocating movement imparted to the cutters across the face of the work is combined, as previously stated, with two other movements. The first of these is an oscillating helical movement to make the cutter follow the lead of the gear to be cut, while the second is a continuous revolution to keep the cutters in unison with the revolution of the work blank.

The first movement (the helical trace) is obtained by guides which are rigidly connected to the respective cutter spindles. The guides have a spiral angle designed to agree with the 30° of the cutters, and are made in three parts, contained in a hollow sleeve. One part is fixed to the sleeve, one connected to the cutter head and free to reciprocate with it, while the third part acts as an adjusting piece as wear takes place.

In action the free part of the helical guide can be compared to an extension of the cutter spindle, having a very coarse pitch thread, and when the main slide moves the cutter head to and fro this extension passes in and out of the other two helical portions which act as a nut. This gives a helical movement to the cutter spindle concerned.

These guides have to control very accurately the helical trace of the cutter teeth. For this reason they are made as large as practicable and are ground very carefully. In this machine the cutters used are 6in. P.C.D., while the guides are 7½in. in diameter. The guides are finished to a master lead screw of the highest accuracy. The first cutter spindle connected to the inner helical guide is hollow, and through it passes a shaft connecting the outer helical guide to the second cutter spindle.

The continuous revolution of the cutters in unison with the gear blank is obtained by means of large indexing worm wheels whose bosses form the hollow sleeves in which the guides are fitted. These wheels are driven by worms on two vertical shafts gearing with a central spindle fitted with a bevel drive at the bottom end, off a horizontal shaft driven by gears from the back of the machine.

In order to obtain the greatest accuracy of pitch, the two indexing worm wheels are made as large as possible; they are nearly three times the diameter of the cutters, which, combined with the ratio of worm to wheel, reduces any possible final variation to infinitesimal limits.

The gears which drive the horizontal shaft referred to also drive, through change wheels, the motion for revolving the blank, and, being in turn driven by belt off a four-step cone pulley, are therefore the means whereby cutter and gear blank are caused to rotate in unison. The pulley itself conveys the drive through a clutch, operated by a lever placed conveniently near the operator, who can instantly stop or start the revolving movement.

In connection with the cutter relief movement already spoken of, to render the movement of each cutter head on its base positive, a cam movement is provided. On the outer end of the crank a cam plate is mounted, and this actuates a rocking shaft on the top of the machine. Links from this shaft connect to a splined shaft in front of the machine, and on this is carried an angular cam lever. At this revolution of the crank the cam levers are made to rock past projecting faces on the cutter heads, thus causing them to move on the slanting bases.

This is done as a precautionary measure, for it is found in practice that the stress on the cam levers is very slight and that the relief action is automatic. Although the withdrawal of the cutters from the work is only 0·032in., it follows that the guides in their index wheels must be kept in correct alignment, and to ensure this a movement is taken from the rocking shaft which operates cams on a shaft mounted in front of the index boxes

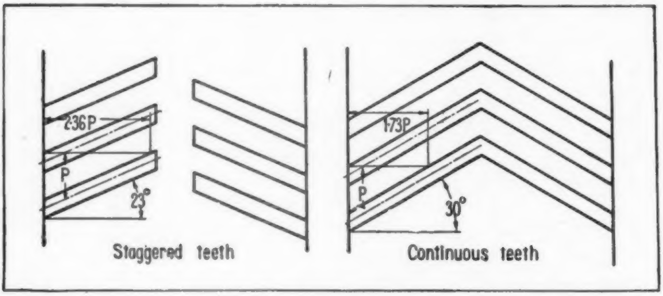


Fig. 2.—Diagram showing how continuity of engagement is obtained.

These are adjusted to give the necessary movement required to maintain alignment with the cutter heads. The index boxes are mounted in machined ways to allow for this movement, and are returned to their proper positions by springs.

The work spindle is mounted in substantial bearings forming part of the work saddle; it is hollow, being bored $3\frac{1}{2}$in. diameter to enable it to take gears integral with shafts. The whole work saddle can be moved towards or away from the cutters by means of a screw and hand wheel, fitted with a micrometer dial reading $\frac{1}{1000}$in., so that the correct depth of tooth is assured.

In setting up work, either the gear is mounted on a suitable mandrel held in an adapter which is spigoted to the face of the work spindle, or it is set up with its own shaft in the hollow spindle and held by dogs on a face plate.

For testing the gear blank for concentricity, the worm of the

large main dividing wheel can be dropped out of mesh and the work revolved by hand.

The main dividing wheel is machined with the same care and accuracy as the cutter indexing wheels. This is essential, as its work is equally important. The diameter is made as large as possible, to minimise the slightest variation. In manufacture the wheels are rough machined and then put aside to recover from initial strains. After finish machining, they are cut with special hobs designed for the purpose.

The wheel is split in a plane at right angles to its axis for the purpose of checking its accuracy and for correcting it during the process of manufacture, on the principles commonly used in astronomical and optical work.

For continuous teeth the cutters have to finish their stroke on the same line, and the cutter heads have to be adjusted for this with crank disc at dead centre. The crank disc is graduated for adjusting the length of stroke. For mounting the cutters, the outer cutter head can be disconnected from the shaft connecting it to its helical guide and moved along the sliding carriage by the screw provided. The cutters must, of course, register correctly with each other, and, to ensure this, provision is made to rotate one cutter with respect to the other.

Referring to the indexing wheels which give the cutters rotary movement in unison with the blank, they are driven by worms which derive their motion from spur gears. The spur gears, however, are not keyed on the worm shafts in the ordinary way, but each has a given number of serrations cut in its boss, and is capable of movement, independent of the worm shaft.

A hand disc wheel having a boss with similar serrations is placed above it, forming a clutch engagement. The hand wheel drives the worm by a feather key.

To adjust the register of the cutters with each other, one hand wheel is declutched and the worm turned through a sufficient amount. This adjustment can be made to 0·0001in. The correction is made when commencing cutting, with the cutters just marking the work.

It will be seen that, by this adjustment, staggered teeth can be cut if desired. Straight teeth can be cut by simply fitting straight guides and straight spur cutters. Internal teeth cutting necessitates changing one cutter spindle.

The next machine, the Sykes No. 4 double helical machine, is on similar lines, but of increased capacity. This machine will cut wheels up to 52in. diameter and 1in. face width, the maximum pitch being $1\frac{1}{4}$ D.P. The cutter bed is the same as in the previous machine. The saddle bed is designed to take the increased capacity referred to, having the saddle carrying faces at different heights.

Sykes Double Helical Gear Generating Machine S.D.H.12.

The success of the foregoing machines on turbine gears led to the design of a machine of a much greater capacity than any yet produced. This machine is known as the Sykes No. 12 gear generator. It has a capacity up to 15ft. diameter and 52in. width of face.

It acts on the same principle as the smaller machine, but in order to handle such large diameters its construction is varied considerably.

The first difference to be noted is that, owing to the heavy

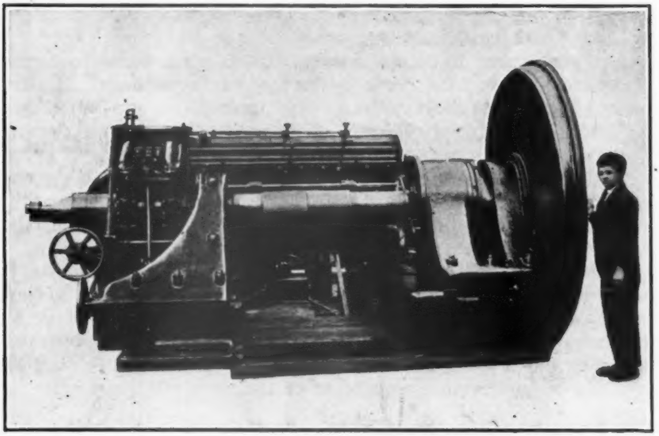


Fig. 3.—The "Sykes" double-helical gear generating machine S.D. H.12.

nature of the work, the work carrying headstock is fixed, and the saddle carrying the cutters is movable along the two main beds. This means that in working the cutters are fed into the blank. Due also to the variety of face widths which this machine can accommodate, a large range of speeds for the crank drive is necessary. For this purpose an eight speed change gear box has been introduced. Another change is in the provision made for running the main work spindle quickly for truing and setting up the gear blank; a separate motor drive is used for this purpose.

The cutters, with their helical guides, indexing wheels, and relieving mechanism, are the same in principle as on the machines already described, the constructional difference being that the saddle carrying them is movable on ways along the bed of the machine. On the near or control side of the machine the saddle

is carried by double ways arranged in two tiers; with this arrangement a more compact drive is obtainable.

The saddle is guided on the upper faces of the bed and is provided with long ways and taper wedges for adjustment. It can be traversed quickly by means of a 4 h.p. motor driving, through a worm gear, a large screw passing through a nut in the saddle. In addition, a slow hand movement is provided through the nut and a small worm, with shafts and bevels, to the micrometer hand wheel in the front of the machine. This hand wheel, through the small worm at the end of the second bevel shaft, causes the saddle nut to revolve, the large screw then remaining stationary. For the fast saddle movement, therefore, the screw is revolved in the fixed nut, while for the slow the nut is revolved on the fixed screw. The micrometer on the hand wheel is graduated to 0.0001 in.

Reverting now to the main drive, from the 15 h.p. motor through the eight-speed gear box, the final driven shaft is splined and passes through a sliding pinion engaging with a large enclosed gear on the crank disc shaft. The crank pin on this disc is fitted in slides and can be adjusted for length of stroke as in the previous machines, giving the required adjustment to suit the work in hand. Driven off the main gear box is a two-speed feed gear case, giving a fine or coarse rotary movement to the cutters and gear blank being cut. This change of movement is arranged through a positive dog clutch and levers operated by two solenoids, which are controlled by a tumbler switch on the operating platform.

On the driven feed shaft is a spring-controlled friction coupling, so adjusted that in the event of any accident occurring to the driven mechanism, slip is provided as a safeguard against damage to other parts. The main dividing and the cutter indexing wheels and other gearing in the system are proportioned so that the driver change wheel in the gears represents the number of teeth in the cutter, while the driven change wheel represents the number of teeth to be cut on the work.

The outer support for the mandrel takes the form of a bracket bearing carried by a heavy saddle, which can be traversed on its base, in the direction parallel with the axis of the main spindle. This movement is obtained by means of the usual screw and nut, and the hand wheel shown in the illustrations. The bearing bracket is detachable and is arranged so as to be quickly interchanged with others of various sizes. It can be lifted away with the work and mandrel, or mounted on the mandrel and slipped into position after the work and faceplate are mounted on the main head stop.

In the case of large and heavy wheels, the mandrel, faceplate and work are usually most conveniently assembled on the shop

floor, while another wheel is being cut on the machine. The whole is then lifted and put into the machine, and to secure it to the machine all that is required is to put into position and tighten up eight bolts holding the back flange of the faceplate up to the flange of the main spindle.

Owing to the size of these machines it has been necessary to ensure by special means the accessibility of all essential controls. With this object the control of the main magnetic clutch, of the saddle traversing motor, and of the fast and slow feed clutches, are all brought to an operating platform. The three-tumbler

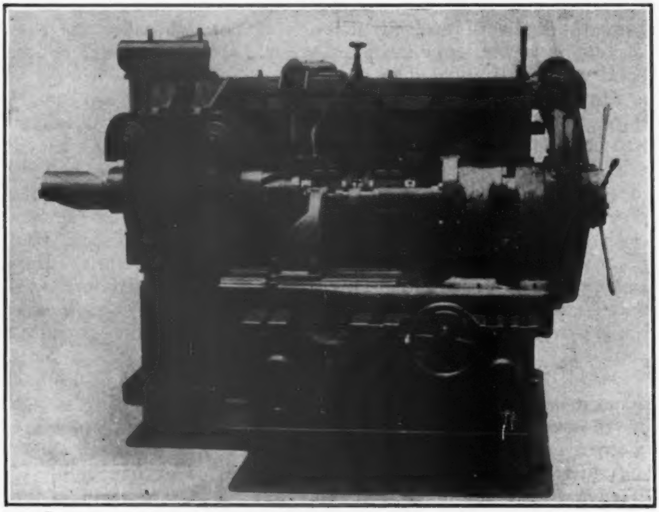


Fig. 4.—The No. 1½ machine.

switches are arranged close together above the indexing wheels. Two are two-way switches, while one is a one-way switch. The last-named operates the magnetic clutch between the 15 h.p. motor and the gear box. One of the two-way switches controls, through an automatic starter, the reversible motor working the main saddle screw, which can be run in either direction.

The operation of the third switch causes one or other of the two solenoids referred to above to be energised, and results in the clutching in of the fast or slow gears for the drive of the indexing and dividing gears. Thus, after the work has been set and the main motor started, all control is from the platform. It

will be noted, further, that the hand wheel for the hand movement of the saddle is also conveniently close to the same station.

The Sykes Gear Generator No. 1½.

The last of the series of Sykes gear generators has been produced within the past year. This is the Sykes gear generator No. 1½; it should be noted that the number of the machine denotes the largest diameter of wheel it will cut in feet.

The No. 1½ machine has been evolved especially for manufacturers requiring a machine with a high rate of cutting and consequently production, which shall at the same time be of sturdy design and capable of cutting gears of considerable pitch. Its capacity is, largest wheel 18 in. diameter, maximum face width 8in., largest pitch 4 D.P. The base has the pump and the cutter cooling liquid embodied in it, the pump being driven off a constant drive from the change speed gear box.

The gear box has four changes of speed selected by a gate change lever, and runs on ball bearings throughout; all gears are double helical and speed changes are effected by internal tooth clutches. The speeds of the driven shaft of the four-speed gear box are 180, 228, 300, 380, with a constant speed of 360 revs. per minute of the driving pulley shaft.

The crank reciprocating the sliding carriage is geared to the driven shaft of the gear box with a 4 : 1 reduction, giving speeds up to 95 reciprocations per minute of the slide. It is possible to raise the constant speed to 500 r.p.m. with a corresponding increase in cutter strokes according to the nature of the work. The crank pin block has a double roller journal bearing, whilst the slide carrying the cutter is of ribbed box section, weight being kept down in view of the high rate of reciprocation, but so distributed as to take all cutting stresses without deflection, the lower portion being provided with oil chambers.

The Feed Mechanism.

In this machine the feed mechanism for rotating gear blank and cutter in unison is driven directly from off the crank disc shaft, which is housed in the four-speed driving gear box. There are four variations of feed obtained by double helical gears and internal dog clutches in a manner similar to the main driving gear box. The lever for changing feed is placed immediately in front of the operator.

A friction clutch is introduced in the driving shaft before it enters the change speed case; this consists of alternate gun-metal and mild steel plates pressed against each other by a coil spring. The spring can be so adjusted that any overload will cause slipping of the plates, and feed will not be transmitted.

As in the previous machines, the change wheel ratios are arranged as 1 : 1, so that all that is required is to mount a change wheel of the same number of teeth as the teeth of the gear to be cut, providing that the pitch gear has the same number of teeth as the cutter, or multiples of these can be used. The dividing wheel mounted on the work spindle is considerably larger than the largest wheel within the capacity of the machine. This reduces still further any possible variation of teeth.

The dividing worm wheel can be lifted clear of the wheel for the purpose of truing the wheel blank. Relief mechanism for the cutter is the same as on the other machines, with the slanting

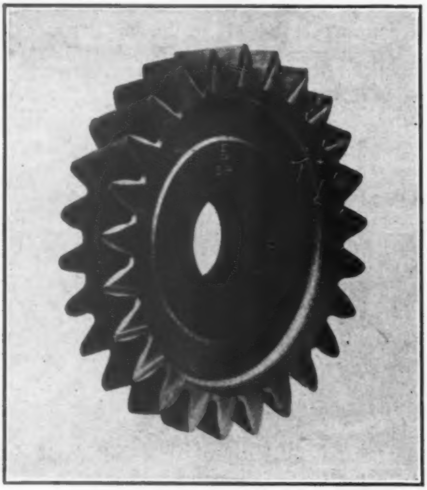


Fig. 5.—A typical pinion cutter.

angle of the base increased. This ensures a rapid withdrawal of the cutters from the work at the end of each working stroke, and is automatic in action.

The index wheel cases carrying the helical guides which are connected to the cutter spindles are kept in alignment during the withdrawal of the cutter and non-cutting stroke by a camshaft driven by mitres from the main four-speed gear box. The drive is by one constant speed pulley, with the loose pulley reduced in diameter to ease the belt when running light. No countershaft is required as the machine can be driven directly off the line shaft.

As would naturally be anticipated, the cutting times, especially for small work on the machine, have proved to be very economical.

Pinion Cutters.

As stated at the commencement of this paper, gear teeth of involute shape possess a number of advantages which appeal to the manufacturing side of engineering. One of these is that the cutters employed in generating the gear teeth can be made with great mechanical accuracy, being themselves original gears.

The principle underlying their manufacture is that of a cylinder rolling on a plane, whilst about the cylinder are mounted flexible bands, the ends of which are held during the rolling action. This, it will be seen, is an application of an involute curve, *i.e.*, the curve traced by a point on a cord when unwound from a cylinder.

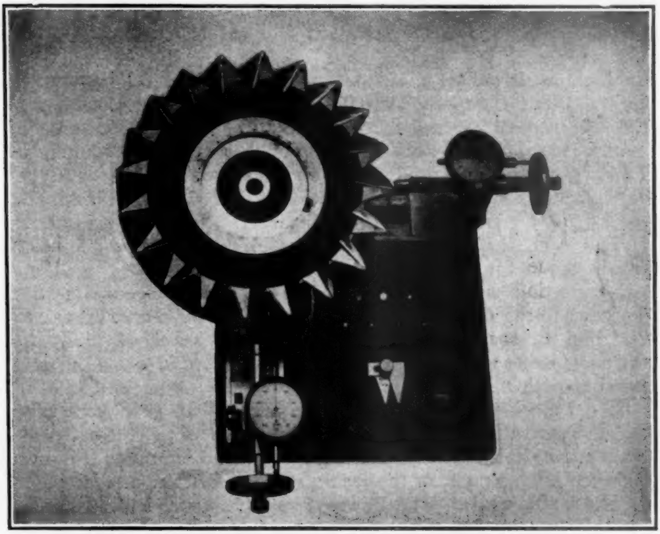


Fig. 6.—The device used for testing cutters.

In our case the cylinder itself is moved. If the cylinder is rigidly connected to a cutter by means of a central shaft, let us say, and the cylinder rolled along the plane, the cutter would mesh with a rack of the same pitch if such were brought in contact with it during the process of rolling.

Now assume that the cutter is a rough finished article; we attach it to the cylinder and commence the rolling action of the cylinder. Also, in place of the rack spoken of before, we introduce one side of one rack tooth and let this side be represented by a grinding wheel revolving at high speed, then, by means of a

graduated adjustment, we can grind one side of our rough finished cutter to a perfect involute curve. If the cylinder be equipped with a suitable dividing mechanism so that tooth by tooth the same process is carried out, all the teeth of a cutter can be treated in this way. That is to say, accurately ground to a true involute curve by mechanical means. For helical cutters the grinding wheel is set over to the correct helical angle and the required relief for clearance is given to each side of the cutter teeth; top relief is also provided for. Face grinding only is needed for sharpening during the entire life of the cutter.

The calculations used in the manufacture of these cutters are dependent upon the pressure angle and pitch circle, the cylinder referred to previously being the base circle of the cutter. A pressure angle of 20° is the standard adopted by the Power Plant Company.

Machines based on the above principle were developed by the Power Plant Company simultaneously with the development of the gear generators, and the rapid, highly accurate production of cutters is to-day a specialised branch of their tool-room equipment. Fellows cutters are produced with the same facility as Sykes cutters, but, owing to the far wider scope of the Sykes machines, the range of Sykes cutters is much larger. They are made from 24 D.P. 4in. P.C.D. up to 1 D.P. 10in. P.C.D. Special cutters can be made for any required pressure angle.

For testing cutters after the final grinding process a testing device has been designed, giving dial readings of 0·0001in. of any variation in spacing and concentricity. A series of plugs for various pitches is used for the tooth spaces and an adjustable jaw for tooth thickness.

In conclusion it should be made clear that gear generating cutters automatically remove any interference when cutting, being gears themselves. When designing gears with high ratios this must be taken into account, or the resulting shape of pinion teeth would be physically weak. The Power Plant Company have a system of enlargement for pinions up to thirty teeth, giving longer addenda, an equal amount being taken off the gear wheels. This gives a greatly improved pinion tooth shape, bringing more involute surface into contact and a larger amount of recess action.

A typical case of this kind is that of the eight-speed change gear box transmitting the drive to the large Sykes machine No. 12. This has been working constantly for three years, and to-day an inspection of these gears shows a perfect surface.

THE DISCUSSION.

MR. KENWORTHY (Member): The description of the Sykes machines has been very well put forward by Mr. Medcalfe, and we are very much indebted to him for this description of a machine which is more or less on novel lines. Mr. Medcalfe mentions that the cutters of these machines are ground on the face, and I should like to know how the true angle of the helix of the gear is maintained. It would appear that the helix of a gear cut with the cutter after it is ground would be a smaller angle. Another point is that the use of a guide for maintaining the angle of the gear may be good whilst the machine is new, but I should think considerable wear would take place on the guide. The wear would be uneven, particularly if gears of different face widths were cut, and consequently, after a little while, the shape of the tooth would not be a true helix. I should like Mr. Medcalfe to say how he gets over this difficulty. There is a further point on which I should like his opinion, and it is one which applies to all gear generating machines. What is his experience of the cutter maintaining a good and true form, and cutting a perfectly clean tooth, when it is continuously cutting tough steel? Personally, I think that one of the greatest objections to gear cutting is that there is a tendency for the gear to rub, the cutter being rendered useless as soon as slight abrasion takes place on the side.

MR. MEDCALFE: The cutters themselves are designed to allow for wear as they are ground back, but if the work is of true outside diameter the helix angle or the pitch circle diameter of the work itself is not affected by that. The mean angle of the cutter itself will be accurate, even though ground back to the last limit of depth. We do not find that undue wear of the guides takes place, but what wear does take place is provided for by the helical adjustable wedge piece in the ordinary way. We have guides in machines to-day which were fitted three years ago, or even more. We do not find the helical face wears unduly, and this applies even when we are cutting wide face widths. There is a large area of contact on the sliding face of the helical guide itself, $1\frac{1}{2}$in. is the actual width of the wearing surface, and there is such a large surface in contact that undue wear does not take place. That is our experience in practice. With regard to the teeth rubbing, relief is given to each side of the helical cutter itself, which is quite sufficient to provide against any rubbing action of the gears being cut. In our experience this problem does not arise, and it should not arise in a properly designed helical gear cutter.

MR. BALE: Does Mr. Medcalfe find that there is any perceptible effect resulting from the use of different lubricants when cutting these large gears? Does he use an ordinary oil lubricant or one of the soda types of lubricant?

MR. MEDCALFE: We use an ordinary cutting lubricant, and have no difficulty, although more care has to be taken, perhaps, in cutting soft mild steel than in cutting the harder material.

MR. BALE: I have found that when using a soda lubricant, or an emulsified oil diluted with water, in many cases there is a rough finish, which can be avoided by using an oil lubricant.

MR. MEDCALFE: We use an oil lubricant in some cases, but usually we use what you call a soda lubricant, with quite satisfactory results.

MR. RAWLINGS (Associated British Machine Tool Makers, Ltd.): In the Sunderland gear generator, the rack shaped cutter has straight-sided teeth, and the cutter edge is set at the angle at which it is required to cut the gear. Since it is easier to produce a cutter with straight-sided teeth, and since it is easier to produce a straight line than a curve, is not the Sunderland generator inherently more accurate than the Sykes? Also, the diameter of the cutter surely decreases when the face is ground, and if a cutter were ground when half way through the cutting of a gear, would not that affect the angle of the helical tooth? How long does it take to sharpen a cutter on the Sykes generator? With the Sunderland machine it is merely a case of passing a grinding wheel straight across the face of the cutter, to get the required relief at the top.

MR. MEDCALFE: For any given D.P. the cutter itself, when ground back, is fed further into the blank. They are, in the first place, designed to have greater than the ordinary tooth depth for the pitch for which they are made, but, if the diameter is correct, that does not affect the helical angle of the wheels being cut. With reference to the Sunderland rack system, it is questionable if the cost is really any lower than in the case of the Sykes, when you remember that a rack itself, even of a fine D.P., can only be compared with a part of a rotary cutter, and therefore, in the course of using the Sunderland rack, you are using the same teeth over and over again, as compared with a rotary cutter of our type. Although you get an apparently lower cost at first, on the whole the cost of our cutters would come equally low. As to accuracy of production, we have no more difficulty in producing our involute shape than they have in producing the rack shape. Such cutters must have a shorter life, tooth for tooth. Obviously, if you have only 6 or 8 teeth in action instead of 12 or 24, you must have a cutter with a life only one-third as long.

MR. RAWLINGS: I was speaking not so much of cost as of the inherent accuracy of the rack type. It is so much easier to produce a straight line accurately than a curve.

MR. MEDCALFE: I do not agree with that. We are in a position to produce the involute curve to an accuracy that you cannot challenge. You can only test it by the tooth form, and I think the two types are on the same level in that respect. It is becoming a debatable point whether it is easier to produce the rack shape than the involute.

MR. RAWLINGS: Do you agree that it is easier to produce a straight line than an involute curve?

MR. MEDCALFE: I am not prepared to agree. It might be quicker,

but I would not say it is easier, having regard to the machinery we have for the purpose.

Mr. Rawlings: There is the question of the guide. The cutter guide on the Sykes machine is of a curved form. In producing different widths of face the wear is localised, and in producing a large number of small face width wheels the wear will take place locally. I suggest it is easier to produce a cutter head travelling in a straight path than in a curved path.

Mr. Medcalfe: If an operator were setting up for the same face width of gear for one week—though that does not very often happen—by putting on another spacing collar before mounting the gear he can use another portion of the guide. It would certainly occur to the shop foreman that, if wear were taking place at one part, he could put on another collar and utilise another part of the guide. We are cutting different widths every day, and the trouble does not occur, or, at least, we are unable to detect it.

Mr. McLeod (Managing Director, Power Plant Co., Ltd.): I think the same objection applies to the Sunderland as to the Sykes machine. If working a short face width it does not matter whether the guide has a helical or a straight face. It is curious that Sykes and Sunderland were very good friends, and when Sykes was working out his first patent, in 1907, he rejected the rack cutter because of its limitation in face width. He designed his machine for helical gears. If you consider a rack cutter cutting a wide faced helical gear, you would have to have the cutter of enormous length, otherwise it would run out of the work. Thus, with the rack you are limited to small faces, but with the Sykes cutter you have no such limitation. As a matter of fact, we have to produce gears up to 54in. face width with the rotary form of cutter, and that would be practically impossible with the rack form. It is not easier to produce a rack cutter than a rotary cutter. Some years ago we made a jig for a wire-netting firm; it was 3ft. long, and we had to space it accurately, we had to obtain accuracy to within 0·0001 in., and we were asked to take the job on on cost, but the firm nearly had a fit when we got the cost out, because it came to nearly £400. It certainly appears easier to produce a long rack cutter, with projections accurately spaced, than to produce a rotary cutter, but I do not think it is so in practice, unless the cutters are short. Some years ago Mr. Sunderland made a cutter 36in. long, to see what could be done, but he had no success, because of the difficulty of obtaining accuracy.

Mr. Gartside (Member): I should like Mr. Medcalfe to say something about the degree of accuracy with which gears can be produced. Also, I should like to know more about the making of the cutters. These, I assume, are ground on the usual Fellows principle, where the tape is on the base circle, and the diameter of the cylinders which carry the tape is the base circle diameter. It is rather difficult to describe the method of modifying the shape of the cutter so that it compensates for the reduction in diameter, but I understand it is on the same principle as the allowance made for increased diameter of pinion? Thus, as the cutter is ground off the face it is reduced in diameter, and I assume the shape alters from front to back, in order to compensate for that?

MR. MEDCALFE: The fact that it has a clearance on each side does not in any way alter the true involute shape of a section through it at any one place, but, as the face of the cutter is ground away, it does, in a very small degree, reduce its diameter, and to overcome that it must be fed into the work slightly.

MR. GARTSIDE: That is arranged, I presume, by the setting of the emery wheel when grinding the cutter? Am I right in assuming that the emery wheel is set, so that you are actually producing a rack which is higher up in position when you are starting the shape of the tooth than when you finish?

MR. MEDCALFE: The cutter teeth are longer than the D.P. they are to cut, of course. When we commence to grind the cutter it has been already roughed out, and we have to surface and produce at the same time the involute curve. As it has already been gashed out practically to the depth required, we have only to grind on the side of the tooth. It is just a matter of cleaning up the roughened surface to get the true involute, exactly on the principle you have described.

MR. GARTSIDE: You mentioned that all the machines have arrangements for testing the work before it is cut. Of course, the cutters are made very accurate, and if there is any eccentricity in the cutter it is fatal.

MR. MEDCALFE: Such inaccuracies would never get past the testing department. The device I have mentioned reads to an accuracy of 0·0001in.

MR. GARTSIDE: When setting up the work, do you test from the hole or the diameter?

MR. MEDCALFE: We test on the actual hole on which the gear will run. It may fit the mandrel, but, if not, we have a series of mandrels, and turn bushes to fit, or, by rotating the blank and clocking it, after tightening up, we can adjust the wheel so that even if mounting one which is not an exact fit on the mandrel, we can get it true on its periphery, and then pull it up tight and get a successful wheel.

MR. RAWLINGS: The helix angle of the work is controlled in some measure by the reduction of the diameter of the cutter. When you grind the cutter its diameter is reduced. In that event, if you are half-way through a gear, do you still get the same helix angle?

MR. MEDCALFE: When you recollect that the cutter is 0·437in. thick, and the top relief is 5·5 deg., there is a reduction in diameter when the cutter is ground right back, but the actual deviation from 30 degs. is nil at P.C. diameter. In any case, the wheel is made with its mating pinion on the same machine, and, if there is deviation, they must fit together.

MR. RAWLINGS: But there must be deviation.

MR. MEDCALFE: Yes.

MR. GARTSIDE: Supposing you take the right-hand helix, does that cut the corresponding helix on the other wheel?

MR. MEDCALFE: No. The right-hand guide, connected to the right-hand cutter, actually cuts the left-hand helix on the blank.

MR. GARTSIDE: In hobbing a spiral gear in a hobbing machine you get an absolutely true spiral, because it is geared up on the

machine by a change wheel. But on the Sunderland machine you actually set to the angle, and there is no gearing up at all. It is necessary for it to be set very accurately.

Mr. Medcalfe: The human element enters into the Sunderland method of setting, of course, and one has to rely on that, in a sense. It is likely to produce quite as much variation as any minute difference in a cutter. In the Sykes method there is no human agency, once the guides are produced, and we are unable to measure any difference in them.

Mr. H. J. Rodgers (Rodgers Bros., Ltd.): Does the Sykes machine carry out odd jobs quickly? In the initial setting up, is there much to do? The machines, especially the smaller model, are quite suitable for odd jobs?

Mr. Medcalfe: You know that you have a certain range of work for a particular machine, and you provide yourself with the necessary mandrels for that work. If the mandrels for the job are in hand, you can mount the job, clamp it up, and have it trued up for concentricity in about two, three or four minutes. So that the time, for a job such as a double helical wheel, including the setting up time, is about twelve minutes. There is no doubt that these machines are very quick, both for mass production work and odd jobs.

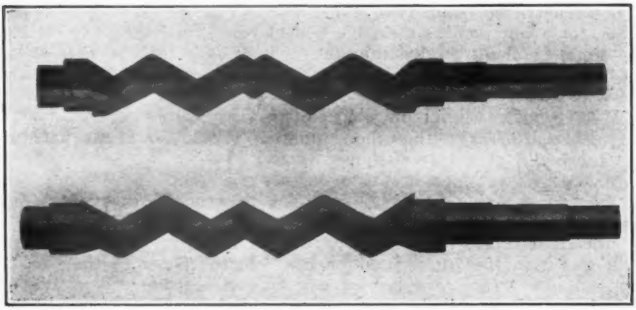
Mr. Rodgers: Sometimes, to suit certain centres, gears have to be made a little larger than the standard. Would the Sykes machine cut these and give a good shaped tooth?

Mr. Medcalfe: Yes, it cuts an equally good tooth; so also does the Fellows machine, and that is one of the gifts that all these machines possess in common.

Mr. Hutchinson (Member of Council): I was rather disappointed that there was not more mention made in the paper of the mathematical and technical side of the gear cuttings, instead of just a description of the Sykes machines. Double helical gears, of course, have a wonderful scope, which is proved by the great increase in their production during the last 15 years. They are principally suitable for very high powers, and also for high gear ratios and high speeds. It seems to me that there is one weak point with the double helical gear, and that is the practical impossibility of tooth grinding. In these days, when it is so important to have very silent running gears, compared with what were looked upon as quiet gears in years gone by, one of the solutions of the problem is undoubtedly tooth grinding, and I should like to know whether, in Mr. Medcalfe's knowledge, there have ever been any experiments made to overcome that difficulty. Among other points I should like to mention, one is that on this machine it seems that the roughing and finishing is all done in the one setting on the machine. I presume that the machines are fairly costly, and should like to know whether preliminary roughing operations on a cheaper form of machine are feasible, as with gears cut on the Fellows machine. Mr. Medcalfe said that the gears were cut to infinitesimal limits of accuracy. What does he term an infinitesimal degree of accuracy? It seems to me that there are four points where error may be introduced, errors which might be reproduced in the gear itself. First, we have the errors in the two

worm wheels; secondly, the error—only very slight—in the cutter; thirdly, the error in the slide itself, which may be appreciable, since it is very difficult to produce a lead screw that has anything less than 0·0001in. periodic error in it; and fourthly, there is the error in the index wheels themselves. I should be grateful if Mr. Medcalfe could say more about the one-tooth pinion, which is an interesting piece of mechanism.

Mr. Medcalfe: With regard to gear tooth grinding, that, I think has been handled mostly by firms outside Great Britain. I was acquainted with the Maag gear grinding machine, which I have admired, and I believe it turns out what is really a fine example of accurate work. But, when one considers the cost of the machine, one cannot help thinking that the extreme degree of accuracy which is claimed—I have no means of checking it—must cost a tremendous amount, and so render the use of the machine uncommercial in the great majority of cases. When I spoke of accuracy to within



Two views of the one-tooth pinion.

infinitesimal limits in the Sykes machine, that had reference to the parts of the machine itself, and I still maintain that we do actually, by special machining processes, by cutting, re-cutting and re-cutting, eliminate error. With regard to the highest class of gearing that we are called upon to do, the final test must be on the gear cut, and if we who cut the gear and pinion are able to see by actual tests, and by the contact of the wheel and pinion, that it is bearing along the entire tooth surface on each helix, then I think we are entitled to claim a very high degree of accuracy. Our checking and inspection system reveals inaccuracies to 0·0001in. With regard to the roughing and finishing of a job on the same machine, we find no difficulty in that, and for good class work we are able both to rough and finish the job with the same cutters.

With regard to the one-tooth pinion, two views of this are shown in the accompanying illustration, and the main facts concerning the gearing may be summarised as follows:—The number of teeth on the wheel is 63, whilst the pitch circle diameters of the pinion and

wheel are 0·508in. and 32·004in. respectively. The outside diameters are 1·756in. and 32·210in., the centre distance being 16·26in. A face width of 6in. and a pressure angle of 22 degs. 10 mins. have been adopted. It will be noted that whilst the ratio of the pitch diameters is 63 to 1, the relationship of the outside diameters is only 18·28 to 1.

The power which it is possible to transmit is, therefore, considerably greater than the small pitch circle diameter of the pinion would lead one to expect. Obviously, it would not be possible to make a straight gear and pinion of this type which would mesh continuously, but by adopting the helical formation the engagement is smooth and continuous.

In an actual test the single tooth pinion has been run under power, transmitting 10 h.p. at 1,000 revolutions per minute for a long period without visible signs of wear. That the efficiency of the drive is not impaired by the unusual construction is shown by the fact that the combination is quite effective when the wheel acts as the driver. Although the exact figure has not been determined by careful tests, it is estimated that the efficiency of the drive will probably reach 97 or 98.5 per cent. This gear is not put forward as a commercial proposition, but should prove of considerable interest to students of reduction gearing, and it may be remarked that models have been supplied to various institutions, including the South Kensington Museum.

Mr. F. R. Martin (Evershed and Vignoles, Ltd.): How small can the gear be made?

Mr. Medcalfe: The outside diameter of the pinion is $1\frac{3}{4}$in., and I do not suppose we could make anything much smaller, to transmit any power without bending.

Mr. McLeod: I do not think that the pinion would be a commercial thing; it is a freak, and there was no intention of putting it forward as a commercial proposition. Obviously, a pinion like that, under sustained load, would bend; its purpose is to illustrate what can be done.

Mr. Hutchinson: Does not the wide difference between the actual ratio of the diameter of the pinion to the gear wheel, compared with the gear ratio, make it less efficient? Is there not much more sliding action on the tooth instead of rolling? Have you any idea of the amount of running in that a double helical gear requires before you get a good surface? There is distortion after hardening, and so on, to be reckoned with, in addition to errors of cutting.

Mr. Medcalfe: I do not think that the ratio of sliding to rolling action is greater than in other involute forms. We do not have hardened gears, so that distortion after hardening does not arise. The wheels, as they come off the machines, may be run in for half-an-hour or an hour, but they do not require more, as a rule. A gear might be slightly noisy, and require a little running in, but we have had jobs which have come off the machines and have not required running in. We have not yet reached the stage at which we can make double helical hardened gears.

Mr. Weatherley (Member): Do you shape double helical bevels?

Mr. Medcalfe: No. Mr. Sykes had this in mind, and may have

taken steps to produce a double helical shaper, but we have no information as to its introduction. It is an idea that a number of people are following up, but, so far as I know, nothing has been agreed upon.

Mr. Mantell (Associate Member): Is the Sykes machine equally as efficient as the hobbing machine for producing spur gears? You have mentioned hobbing once or twice, and I wondered whether you still use it.

Mr. Medcalfe: I think that, for a straight spur, a Sykes gear generator would come out ahead, both in regard to the time taken and the degree of accuracy. The Sykes machine, which can be used for a variety of work, is set up more especially for double helical work. Although we can do straight spur gear cutting with it, we do not go in for it, because the machines are always busy with double helical work. Undoubtedly, the Sykes machine is equally as efficient as a hobbing machine for producing spur gears, and you have the advantage of being able to cut double helical gears also at any time. To settle the matter, we should want data covering a long period, but, looking at it from the spur gear point of view alone, there would not seem to be much difference between the two machines.

Mr. Hutchinson: Then you have the great objection that you cannot cut hardened gears. Can you cut gears with a hardness up to 90 or 100 tons?

Mr. McLeod: Yes. We cut toughened gears, and can cut anything not quite so hard as the cutter.

Mr. Gartside: With this machine, the least chip out of the cutter will mean that it has to be scrapped, but a hobber can be run with half-a-dozen teeth out of the cutter.

Mr. Medcalfe: You can grind the cutter.

Mr. Gartside: Have you seen a Fellows cutter with a tooth out and which is still working?

Mr. Weatherley: With regard to the grinding of these cutters, I think the Sunderland cutter has an advantage over the Sykes or Fellows, or any other similar cutter, inasmuch as it is possible to control the diameter of the grinding wheel more easily with a straight tooth having a larger face than with one having only a single point of contact.

Mr. Rawlings: Supposing you wished to cut a 20-inch gear wheel, and you found the ratio of your change wheels and the diameter of your cutter and former gave, say, 30 degrees helix angle, what is the next size downwards at which you would get the right combination for using the same size of cutter?

Mr. Medcalfe: We are using cutters of the same type and design all the time. We do not put in cutters of different diameter except in special cases, which are very rare. In standard work we use a cutter of 6-inch pitch circle diameter.

Mr. Rawlings: Yes, but supposing the gear wheel were 19 inches instead of 20 inches. In that case, the helix angle would be different for the same setting.

Mr. Medcalfe: No, not across the face.

Mr. Hutchinson : I do not quite agree with Mr. Rawlings, because I do not see how it would be possible to produce a rack cutter as accurately as a circular cutter can be produced.

Mr. Gartside : I do not agree. We can measure the pitch of a worm quite easily, and can produce a rack, without measuring rods, that would be absolutely dead true to one-millionth of an inch, if desired. That can be done by spacing lengthwise, but no means has yet been devised for dividing up a circle without error.

Mr. Medcalfe : In what terms does the machine measure?

Mr. Gartside : I could not give exact figures; the machine was exhibited by Messrs. Herbert at the Machine Tool Exhibition. However, a degree of accuracy of a millionth hardly enters into commercial work at the moment.

Mr. McLeod : One of the most accurate dividing machines in the world is that made in London by Messrs. Watt, the mathematical instrument makers. The wheel was made some years before the war for dividing theodolites and for astronomical instruments. In this instrument error is eliminated progressively, or practically eliminated. Of course, we can never get absolute accuracy, and the thing is to reduce errors to the minimum. People speak of accuracy in a more or less haphazard way, as if there were no error, but there is always an error.

Mr. Hutchinson : That is why I have asked what are the limits of accuracy within which these gears can be produced. I have had no figures with regard to the tooth-to-tooth error.

Mr. Medcalfe : We should pass 0.0002 in.

Mr. Wilson (W. H. Allen & Co.) : What would be the cumulative error on a wheel with a diameter of 5ft.? I refer to the cumulative tooth-to-tooth error, not the circular pitch error.

Mr. Medcalfe : The total error would not be more than 0.0005in. I have no figures regarding tooth-to-tooth error, as that is a matter for the inspection department. From one side of the wheel to the other, 0.0005in. is regarded as good.

Mr. McLeod : Cumulative error does not matter, unless it is pronounced. You have given the tooth-to-tooth error, and if that is kept within reasonable limits you ought to get good results.

Mr. Wilson : I do not think you can take the measurement of the gear by taking the circular pitches alone. It is the practice to take the pitches of, say, 20 teeth, and calculate the cumulative error round the wheel on that basis. I have made workshop instruments myself, and I have also tested gear wheels 6ft. in diameter, and have found a cumulative error up to 0.009in. round such wheels.

Mr. Martin : Does Mr. McLeod say that cumulative errors do not matter?

Mr. McLeod : Unless they are pronounced. If you test a wheel tooth for tooth and find it is within reasonable accuracy, it will run. If there is an appreciable error at any particular point, there will be noise as the pinion passes that point.

Mr. Martin : But we do not always want to use gears for power transmission. I am connected with a firm who use them for other purposes, such as the control of guns for firing at long ranges. There the cumulative error is a serious matter.

MR. McLEOD: Yes, but I was speaking of the purposes for which gears are mainly employed.

MR. MARTIN: You are anxious, of course, to further the use of the double helical gear, and that is quite right, but there is still a large field for the ordinary spur gear, even in the case of motor cars. I think that use will continue, and will grow, because of the sliding action.

MR. MEDCALFE: But why adopt the sliding motion?

MR. MARTIN: Because it is cheaper.

MR. MEDCALFE: If we can make a gear box as cheaply on the double helical system as on the spur gear system, there is no reason to adhere to the old-fashioned method.

MR. MARTIN: Could you produce it as cheaply as the present type?

MR. MEDCALFE: There is every reason to think we could, and I think the motor car manufacturers themselves believe so, but to say so definitely at the moment would perhaps be speaking prematurely.

MR. GARTSIDE: I have great faith that, before very long, if we can produce a commercial gear grinder, the gear hobbing machine will come into its own.

MR. HUTCHINSON: What about the other firms that are producing gear grinders? They are commercial?

MR. GARTSIDE: Up to a point.

MR. HUTCHINSON: They grind such gears as those for motor car work quickly, cheaply, and to a very high degree of accuracy.

MR. GARTSIDE: That is true, but manufacturers are calling for a still higher degree of accuracy. Why should the firm have a Maag machine, costing £2,000, whilst another will install a Lees-Bradner at half the price? It is a question of accuracy.

MR. HUTCHINSON: How is it that the makers of cheap cars to-day are grinding their gears?

MR. GARTSIDE: Because we have the Lees-Bradner machine, and there is also the Fellows machine itself.

MR. HUTCHINSON: There are only about five firms in the country using them.

MR. GARTSIDE: I should say it is probably the best machine on the market, at the price, for commercial work.

A MEMBER: I believe the machine calls for a very high degree of accuracy in the material to be ground.

MR. HUTCHINSON: That is the case with any type of work produced to close limits. Work must be roughed out accurately in order to finish it accurately. That is the secret of precision work.

MR. GARTSIDE: The great disadvantage of the hobbing machine is that flats are left on the teeth. If a hob can be made with, say, six starts on it, the wheel will go round six times as quickly, and the same work can be done in a sixth of the time, but it would not be accurate enough for commercial practice. If the wheels must afterwards be ground, then the hobbing machine is a roughing-out machine; the Fellows is also a roughing-out machine when the work is subsequently ground. If you can produce gear grinders to do the work quickly enough, then you can work more quickly with a hob than with another machine, but you are limited by the shape of the teeth.

MR. WILSON : Do you get the same rigidity with the wheel blank mounted on a mandrel as obtained on the Muir machine where the wheel is mounted direct on the table vertically?

MR. MEDCALFE : Yes. We have made the machines extremely strong, and within their capacity we do get that rigidity. That is why we have a massive base plate and dividing wheel.

MR. HUTCHINSON : I will take the opportunity, for which I am grateful, to propose a vote of thanks to Mr. Medcalfe for his paper. There are a number of gentlemen here who are not members of the Institution, but we hope it will not be long before they are members. We are struggling very hard to make our discussions interesting; the Council look upon the discussion as playing a very large part of the utility of a paper, and we are glad to hear the remarks of visitors. I can assure those who are not members that the Institution is becoming a real factor in the lives of production engineers, and before many years, without doubt, it will be one of the leading institutions in the country. The field in front of it is very great; we have received many letters from people high up in the engineering world, and we feel very greatly encouraged by their interest.

MR. MEDCALFE : It has been a pleasure to come here. If I have added to your store of knowledge I shall feel amply rewarded.

COMMUNICATIONS.

Sir,—During the dicussion that followed the reading of Mr. Medcalfe's most interesting paper at the last meeting of the Institution of Production Engineers mention was made of the fundamentally correct principles of the Sykes gear shaper. Nevertheless, it appears that the use of a helical former to obtain the helical tooth is not in accordance with the true principle of generation. Surely a generated helix is the path traced on a revolving cylinder by a point travelling in a straight line parallel to the axis of the cylinder and at a distance from the axis equal to the radius of the cylinder. This principle, of course, is employed when screw-cutting on a lathe. Another method of generating a helix on a cylinder is to travel a point along the path of the developed helix in a plane tangential to the cylinder. With the requisite rolling motion the helix is generated in the same way as a circle is generated by an infinite number of tangents This is the principle employed in the Sunderland helical gear planer.

When viewed from the practical standpoint the objection to the helical former appears to be the inaccuracy caused by wear. Although adjustment may be provided to compensate for wear, the point of wear has first to be located—a difficult matter on a helix former, although, of course, this is quite simple on the straight cutter slides employed on the Sunderland machines. In connection with the comparative accuracy of a helical former and a straight slide, it is obvious that, given the same care in the production of each (a condition that there is every reason to assume), then the more definite straight element is naturally more accurately produced. In the same circumstances it is easier to produce straight-sided teeth accurately spaced in a straight line, as in the Sunderland cutter, than it is to produce involute curved teeth accurately spaced around a circle as in the Sykes cutter, especially when the difficulty of gauging an involute curve and, to put it mildly, the difficulties of dividing a circle without error are considered.

Whilst on the subject of cutters, it is interesting to consider the comparative simplicity of sharpening Sunderland cutters against the operations required to sharpen a Sykes cutter. The question of sharpening Sykes cutters also raises an interesting point. Due to the clearance angle, the outside diameter of the Sykes cutter is reduced by grinding the face for sharpening. Now the helix angle is controlled by the cutter diameter according to the mathematical formula obtained as follows :—

Let D = diameter of cutter,
A = angle of rotation of cutter during the cut (in degrees),
B = helix angle of gear tooth (in degrees),
H = vertical co-ordinate of developed helix of gear,
W = horizontal co-ordinate of developed helix of gear.

Then $\frac{H}{W} = \tan B$. Therefore H controls helix angle,

but $H = \frac{\pi D \times A}{360}$. Therefore D (diameter of cutter) controls the helix angle.

It is thus obvious that if a gear is being cut that is sufficiently large, or is of tough material so that the cutter must be ground during the cut, then the helix angle of that gear will vary according to the number of times that the cutter is ground. This variation is slight, perhaps, but still it exists.

It is realised that these points are concerned mainly with fundamental correctness, but, nevertheless, they have important reference to the recognised fact that, given the same care in construction, the machine that operates on fundamentally correct principles is the one most likely to produce accurate work. G. W. RAWLINGS.

Tech. Dept., A.B.M.T.M., Ltd.

Sir,—In reply to Mr. G. W. Rawlings' interesting letter in reference to my paper on "Gear Shaping," given at the meeting of the Institution of Production Engineers on November 21st, I should like to emphasise the following points :—

Mr. Rawlings commences by describing a " guide " as a " former." This description can be applied to all guides which give a prescribed path to a cutting tool, but the term is erroneous in this case because it implies a device which determines the shape of the product, not necessarily the path of the tool.

The guide on the Sykes machine makes the tool take a helical path (or a straight path if a straight guide be used), the shape of the tooth being decided by the tool and the spacing by the mechanism of the machine. The Sunderland machine does the same thing in a different way, and therefore, if the helical guide is a former, so in the same manner is the tilted guide of the Sunderland machine, in accordance with Mr. Rawlings' own logic.

On the question of wear, your correspondent labours the points and would have us believe that only on flat surfaces is it possible to locate wear; surely this question is not based on practical considerations. We experience no difficulty in testing guides for wear, using the same means by which they are generated; such tests, however, have shown that the accuracy of the helical angle is maintained.

Regarding the question of comparative accuracy of one system with another, surely this depends on the organisation and the provision of suitable equipment; therefore, given the means, it is just as easy to produce the requisite accuracy in one as the other. This applies to the production of rack or pinion cutters, with the weight of evidence in favour of the division of a circle. If this were not so, dividing engines for marking measuring tools would be fitted with divided racks instead of divided circles, which mathematical instrument makers use.

On the question of variation of helical angle due to face grinding the pinion cutter, it is evident that further enlightenment is neces-

sary. The formula quoted by Mr. Rawlings is, of course, correct, granting that D equals P.C. dia. of cutter; but his assumption that the pitch circle diameter is reduced is not correct. The pitch circle (or cylinder) is parallel to the bore of the cutter, and the small variation of the cutter lies in its outside diameter when new, and not in the pitch circle diameter and consequent helical angle.

The result in practice is that a small amount of additional dedendum clearance is given to a gear being cut with a new cutter, the spacing and thickness of the gear being cut depending upon the dividing wheel. In reply to Mr. Rawlings' question during the discussion of the paper, the deviation referred to above was meant to be understood, not a deviation of the helical angle, which does not vary at any time, and in this respect I wish to amend my reply.

It is clear, therefore, that the principles on which the Sykes gear generator is based are fundamentally correct as stated in my paper.

West Drayton. O. H. Medcalfe.

Sir,—The discussion on Mr. Medcalfe's paper, read before the Institution of Production Engineers and published in *Engineering Production,* and the correspondence on the same matter, tempt me to offer some criticisms of the critics.

The principle upon which the Sykes machine has been built up is that of the Fellows gear generator, and Mr. Sykes would doubtless be the first to admit this. It is, however, in the adaptation of the Fellows principle to the cutting of double helical gears and in the design of machines for cutting large gears that the Sykes machine has exhibited original features, and those who are acquainted with it will admit its value in spite of the very theoretical criticisms which have been levelled against it. It is doubtless true that the helical guides on the Sykes machine wear. It is also a fact that all the bearings wear, and that all the other sliding parts wear, and that this wear, if serious, would have a detrimental effect upon the product. The fact that a satisfactory commercial product is produced by the machine is evidence that the wear is not serious, and I think the same might be said of some of the other machines which were claimed in the discussion to be superior to the Sykes machine in respect of wear.

As a user of the Sunderland machine I fully appreciate the satisfactory commercial work performed by it, both on straight spur gears and on double helical gears, but it is not unfair to suggest that wear takes place on the Sunderland machine at least to the same extent as on the Sykes machine. For example, the main spindle and also the worm and worm wheel which control the rotation of the work blank are constantly at work, and must be constantly wearing, and if more wear should take place at one part of the worm wheel than at another the effect upon the accuracy of the product might be serious. In the same way the screw which feeds the Sunderland cutter in the tangential direction is subject to wear, and such wear, if serious, must lead to inaccurate work.

On some of the Sunderland machines the cutter is retracted from the work after each cycle of operations, and has to be brought back

to exactly the same position each time, so that during both roughing and finishing cuts the cutter must be taken away from the work and brought back as many times as there are teeth in the gear being cut. The wearing of the parts, if serious in amount, would render it difficult to ensure this accurate replacement, so that bad work would result. Similar criticisms can be levelled at the highly successful Fellows machine, at the hobbing machine, and probably at every other machine tool of every kind ever made for any purpose whatsoever.

The real test of a machine tool is whether it will do the required quality of work in the required time, and whether in doing so it will maintain the quantity and quality of its output for at least as long as its competitors.

I do not know that any reflections have been cast upon the quality of the work actually produced by the Sykes machine, any more than by the other types of machines mentioned, but I do suggest that the machine has been rather over-criticised.

The purchaser of a machine should undoubtedly examine fully its design and construction to satisfy himself that he is buying the right thing, but it seems open to question whether advocates of alternative machines are wise in offering criticisms which are just as applicable to their own products.

The only way to avoid wear of the working parts of a machine tool appears to be to refrain from using it, which would suit neither the buyer nor the seller.

P. V. VERNON.

Coventry.

(Alfred Herbert, Ltd.)

THE

INSTITUTION OF PRODUCTION ENGINEERS.

A GENERAL Meeting of the Institution was held at the Engineers' Club, Coventry Street, London, W.1, on Friday, December 12th, Mr. Butler, Vice-President, being in the Chair.

The Minutes of the previous meeting were read and approved.

Mr. C. D. Andrew, of Sir W. G. Armstrong, Whitworth & Co., Ltd., Ashton Road, Openshaw, Manchester, then read a paper on "Heavy Machine Tools." Exhibits consisting of cutting tools, together with chips and metal cuttings of an exceptional nature, were examined by members and visitors, and an interesting discussion followed.

HEAVY MACHINE TOOLS.

By Mr. C. D. ANDREW, M.I.Mech.E., of Sir W. G. Armstrong Whitworth & Co., Ltd.

The object of this paper is to present to the members of this Institution some observations regarding heavy machine tools, more especially with reference to the methods of production of work upon them, and some general remarks on certain developments of design to meet modern conditions.

The history of the heavy machine tool is one of great interest, but its written record is of a disconnected and incomplete character, and this is probably due to the fact that the engineers who have been most closely connected with the development of the various types have been so fully occupied with their task that none of them has had sufficient leisure to compile a review of the successive steps in their evolution from the date when hand tools for large operations were superseded by power-driven machinery. Although the older members present will possess what may be called a traditional knowledge of the history of machine tools, it may be of interest to them as well as to the younger members to recall in a brief manner some part of the history of the subject.

The heavier types of machines for the working of metal appear to have had their origin mainly in France and England. As was perfectly natural, the large lathe was the first to be produced, of a simple horizontal type with hand tools and plain rest, apparently closely followed by the vertical boring machine. Thus large lathes of a useful type are recorded in France about the year 1770, and in England about 1790. This was, of course, previous to the effective application of steam power for driving machine tools, as, although steam engines were in existence, they do not appear to have been sufficiently developed for workshop use.

Strange as it may seem to us now, it is a fact that the engineers who were contemporary with James Watt, and even that great inventor himself, had misgivings about the application of a crank to convert the reciprocating action in a steam cylinder into a rotary motion. The use of a crank for such a purpose was derided by some engineers, as it was supposed that the momentum of the steam-driven parts would carry away any ordinary crankpin on reaching the dead centre. This idea is revealed in the corre-

spondence which took place between Watt and his friends before the crank was actually introduced as a workable proposition.

It is a curious fact in connection with methods of production of machine tools that one has only to get off the beaten track by visiting certain out-of-the-way parts of Europe to discover still in use many of the earliest types of machine tools on which the production of work is only one-sixth to one-eighth of that done on recent types. In such cases, if one exhibits cuttings such as are now taken in ordinary practice in well-equipped shops, it is sometimes extremely difficult to persuade the users of this old machinery that the cuttings have been taken off machines which still retain the same general appearance as that of their prototypes.

To revert for a moment to the earlier period, an interesting book is in existence, a copy of which the author has had the privilege of inspecting in the library of a foreign arsenal. The text of this book was prepared in lithographed handwriting and was in the form of a voluminous report to the Emperor Napoleon I. by one of his engineers, stating the resources of French industry for the manufacture of guns. It is fully illustrated with well-drawn views of machinery, most of which were vertical boring machines for the boring of bronze guns. The gun casting was suspended in a vertical position, muzzle downwards, and bored with tools of almost exactly the same shape as are used nowadays. The boring heads on the bars were cut away and fitted with flat blades as they are in present-day practice. The vertical boring bar was chucked in a horizontal table of large diameter, fitted with hard wood cogs. At a convenient distance from the table and tripod, a circular track was arranged around which one or more horses operated a "roundabout" to provide the driving power, which in this case was real "horsepower," the connection being by bevelled gears and pinion to the table.

Another method also shown and which was apparently of more frequent application was the use of running water, such as mill-streams and rivers, even chapels being pressed into service for this purpose when they happened to be situated near the banks of a river. In one instance the boring machines were shown installed in a barge moored in midstream, with paddle wheels at either side to provide power.

Judging by the literature available, it is evident that the warlike actions of the French nation at that period gave a considerable impetus to the mechanical arts and to the inventive faculties of the engineer, just as occurred recently in the Great War.

Evidence of activity in large lathe development is shown in French literature towards the end of the eighteenth century, and about ten years before the close of that century Maudslay introduced his lathe with slide rest.

The planing machine in its first effective shape and in general

outline, having the appearance with which we are acquainted, was introduced by Clements nearly one hundred years ago, operated by man-power, although he appears to have used a simpler machine about 1820. He was closely followed by Joseph Whitworth and Roberts. It is somewhat difficult at this date to say who actually made the first experiments, as some kind of a mechanical planer was used 110 years ago. These earlier machines embodied the same principles which are still contained in modern machines. Thus, for instance, the older machines used both the screw and the rack for driving. For a long period of time no striking improvements were introduced in planers, although such details as method of belt drive were improved. With the advent of high-speed steel, however, that is, in recent years, it became necessary to improve the design, which was done by the universal use of cut gearing and the more frequent use of the rack-driven or spiral gear-driven types of table. While the screw drive for the table is an excellent method, it does not lend itself to high speeds, and, except in the case of slow-moving machines, such as armour-plate planers, it has been almost entirely superseded by the rack for driving, which if well cut and geared into a bull wheel of sufficiently large diameter allows of the use of high speeds without jar.

In a modern general workshop where it is desirable to obtain maximum output, the planing machine might be considered the most important tool, as it is frequently the case that subsidiary elements of construction turned out on lathes, boring machines, etc., can be handled and machined quickly, while the heavier elements which should be machined on the planer are liable to take up considerable time. It is therefore essential from the point of view of production to develop as much improvement as is possible in the design of planing machines. At the same time, the average user wishes to obtain a machine which is not too complicated or too costly, and there still remains much to be done in order to combine simplicity with efficiency.

The question of the form which the planer drive should take is of such a character that it could only be satisfactorily dealt with in a very lengthy paper. An efficient drive which has been very much used and gives good results in continuous work is that embodying a magnetic clutch. The Lancashire drive or motor generator type, while being more expensive, is recommended to suit certain conditions, and there are two or three different forms of direct reversing motor drive.

The shaping machine is, of course, a modified form of planer, and the general tendency appears to be to favour quick cutting small planers rather than shapers where it is convenient to do so.

With regard to lathe work, it should be noted that the tendency is to cut out small lathes as far as possible in favour of com-

bination lathes and small turret lathes, as it is found that the greater proportion of the details which have to be made in a modern shop are machined more quickly and profitably on combination machines, turret lathes, semi-automatics, and full automatics rather than on small plain lathes.

The illustration (fig. 1) shows an armour-plate planer, which gives great efficiency in practice. It will be seen that the table is driven by two powerful screws, one on each side of the bed, and these screws are driven through straight spur gears from the motor, located at one end of the machine in between the screws, reversal being provided for cutting on both forward and return strokes. When cutting armour plate of the usual characteristics, the speed of cut in both directions is 15ft. per minute, feed $\frac{1}{20}$in., depth of cut $\frac{1}{4}$in., and there are fourteen tools cutting simultaneously (twenty-eight tools being carried in the holders). A range of 10ft. to 20ft. is provided, the motor being 60 h.p. The machine will plane 16ft. long by 18ft. wide. Cuttings are exhibited from this machine.

The next illustration, fig. 2, shows a lathe constructed for testing purposes, 18in. height of centres, driven by a 60 h.p. motor, and with single helical gearing of 10° angle. On mild steel of 35 tons tensile with a trace of nickel, this machine has taken test cuts of a section $1\frac{1}{4}$in. by $\frac{1}{4}$in. at 32ft. per minute cutting speed

Apart from the subject of the planer and the lathe which, in one form or another, form the basis of machine shop practice, it is not proposed in this short paper to discuss types which have arisen from that basis, as our object is rather to consider the question of production.

Since the Armistice of 1918, most of the heavy machine tool makers have turned their attention to the question of machinery made necessary by the obsolescence of the motive power and rolling stock of the various railway systems throughout the world, as it is, of course, realised that there is a great deal to be done in this direction. The design of railway machinery in this country was quite naturally practically at a standstill during the period of the war, and until reorganisation had commenced after 1918. The renewal of plant for railway work has, therefore, been concentrated upon by a large number of English makers, and those who were equipped to turn out heavy machines have paid more attention probably than ever before to the design of machines for locomotive building and the moving parts of coaches and wagons, viz., wheel centres, tyres, axles, etc. I will give a brief summary of methods and changes which have been followed in this direction.

The cylinder boring machine has until a recent date shown no particular advance in design in this country, but has remained as it was originally constructed, viz., with the boring bar carrying

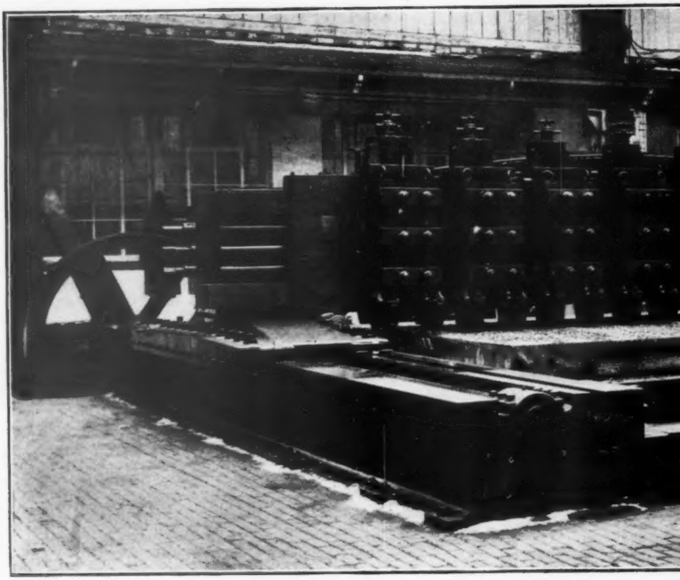


Fig. 1.—Armour pl

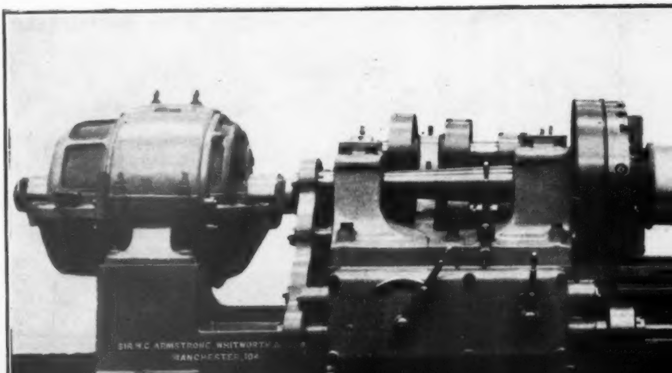
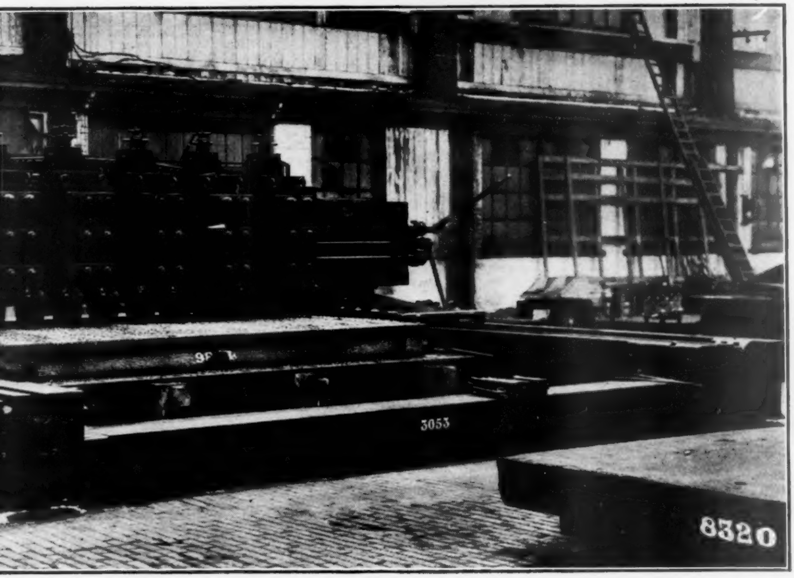


Fig. 2.—



.—Armour plate planing machine.

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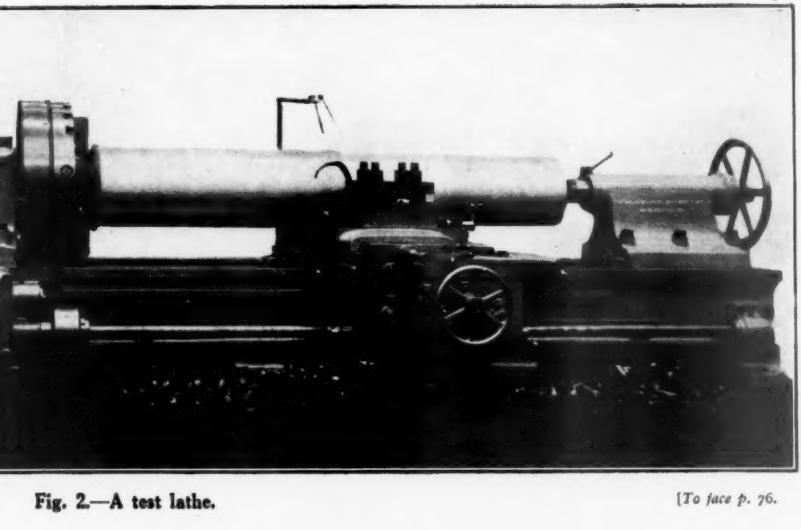

Fig. 2.—A test lathe.

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a boring head which was caused to travel along the bar by screw feed, the cylinder casting being packed on a stationary bedplate. A view of this type is shown in fig. 3. The difficulty with that design has always been that the boring bars themselves have had to be withdrawn from the cylinder before the cylinder casting could be removed from the machine, and this difficulty was emphasised when the boring was done from both ends of the casting, *i.e.*, two bars at each end boring the main barrel and piston valve chamber respectively. A simplification of the method has recently been introduced by means of which the cylinder casting instead of remaining stationary is fed forward on a travelling table, the boring bar remaining in its original position.

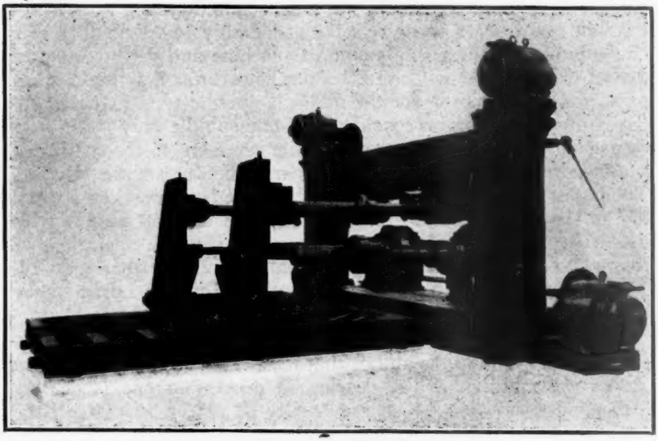


Fig. 3.—Large cylinder boring machine.

It is obvious that as the cylinder casting can be bodily withdrawn from the boring bars by this method the operation is much better and quicker. Previously the time taken in setting and removing an average pair of locomotive cylinder castings was about four hours, the machining operation itself taking about eleven hours. With the travelling table the setting and removing occupies one hour and the machining itself about 9¼ hours per pair.

Another mechanical problem to which a considerable amount of attention has been paid is that of the drilling of boiler shells and fire-boxes, and there appears to be room for improvement from the point of view of output. In an average modern locomotive shell and fire-box there are approximately 1,500 holes to be drilled after the shell and box have been bolted together temporarily.

An important question which arises in this connection is whether the final result is better by the use of one drilling spindle in a machine intended for this purpose, or if there should be two, three, or four spindles employed. It is impossible in the limits of a short paper to do more than state approximately what is claimed for the respective methods of single spindle *versus* multiple spindles.

It is quite certain that a much more powerful drive can be employed with a single spindle unless some method is introduced of a better character than a drive by ordinary small straight spur gears. Thus the spindles when multiple should either be driven through universal swivel joints, or be so close together that a direct drive on each spindle is impracticable, and the power which can be applied to each individual spindle being transmitted through equal gears or swivels is considerably less than that with one spindle. With a single spindle machine and direct drive the output is about one hundred holes per hour through a single thickness, and it is claimed for the multiple spindle type that the output is greater but varies considerably, one spindle only being used occasionally. It might be worth while referring to the conditions which govern this problem, as it is not one for simple solution. The boiler shell, to which is attached the fire-box, must, on account of the shape of the fire-box, approach towards and recede from the drill or drills, and it must, of course, between operations be rotated to different positions. It is also necessary that the drill upright must be movable across the work and that the drill saddle must be movable vertically.

With one spindle there are no complications whatever; with two or more it appears to the author that it is difficult to make sufficient use of the multiple drills, bearing in mind that one is dealing with a piece of work which can hardly be placed so that all the lines of holes will be in sufficiently exact alignment with the elements of the machine itself; also, that the shape of the shell and box is such that many of the holes can only be drilled singly. There is also to be considered in connection with this problem the pressure of the drill point upon the shell of the boiler, particularly when drilling near to the unsupported end of the shell. It would be interesting to ascertain in connection with such work as this, which is not of a precision character, whether location of the point to be drilled, which can be effected more quickly with a single spindle, in which case it would seem that considerably more direct drive can be applied to the spindle, is not at least equal to the method with multiple spindles, where location of drill point is not so easy and individual pressure not so great under ordinary conditions.

In fig. 4 is shown a boring and turning mill with 8ft. diameter table. On such work as large pulleys this type of machine is

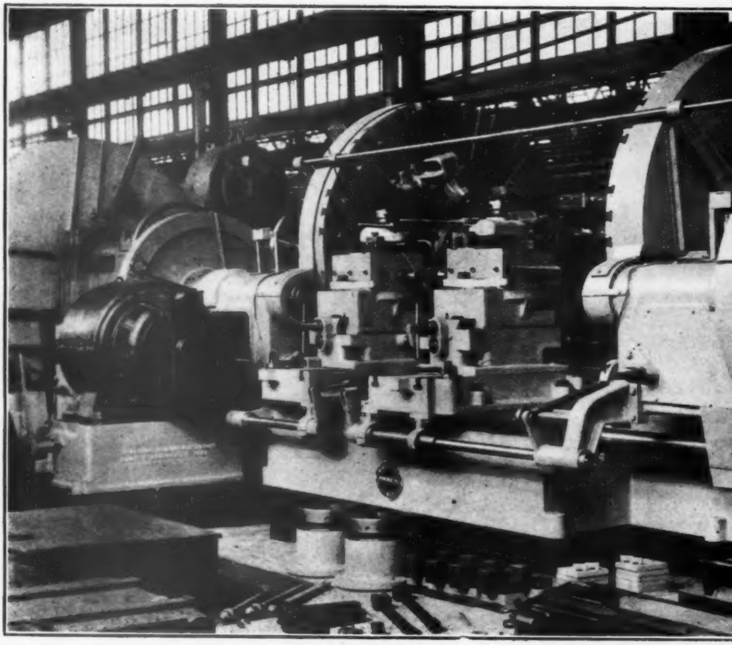
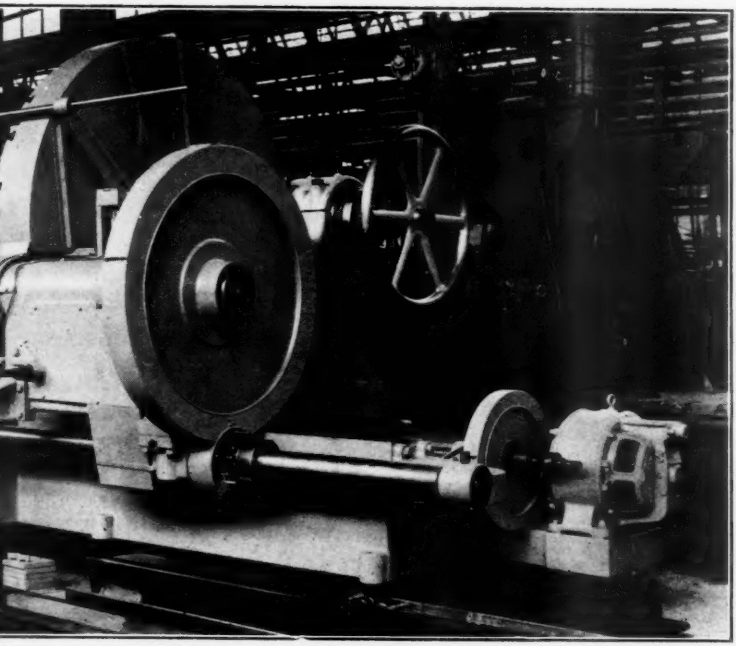


Fig. 5.—A modern whe



A modern wheel lathe.

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capable of doing two to three times as much as an ordinary horizontal lathe, as will be seen by the examination of a representative piece of work which is exhibited.

Another illustration, fig. 5, shows a heavy locomotive wheel lathe with tool holders fastened down, dispensing with the usual

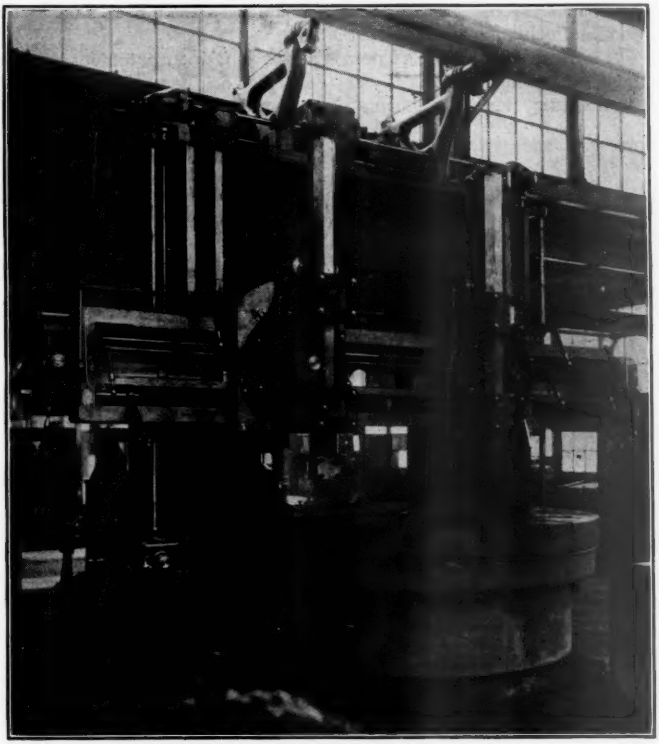


Fig. 4.—A large boring and turning mill.

clamps. This machine was recently built for a foreign railway, and its output is a pair of 6ft. wheels re-turned after service on the road in 45 minutes, floor to floor. Three roughing tools are used in each rest, and a forming blade to finish.

The wagon or coach wheel lathe shown in fig. 6 is in use in English railway workshops. The output actually obtained is a

pair of worn wagon wheels, re-turned after service, in 12 minutes floor to floor.

A horizontal machine for wagon wheel centres is shown in fig. 7. This does all the machining necessary on the wheel centre forging or casting at one setting, completely finishing it ready for use, the floor to floor time being 45 minutes. (In practice 54 wheel centres in three eight-hour shifts is actually the production on a double machine with two faceplates.)

A horizontal machine of new construction, with patented attachment for boring tyres, is illustrated in fig. 8. It will be seen that all necessary tools for boring are mounted in the rams, roughing

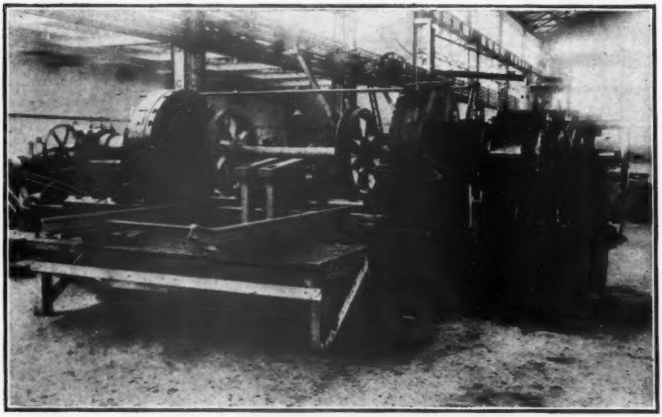


Fig. 6.—A wheel lathe with loading gantry.

on one side and finishing on the other, and simultaneously with the boring operation a grooving tool cuts the recess for the retaining ring. There is no change of tools necessary.

For purposes of comparison with ordinary lathe work, a slide is shown of a piece of work done on an improved semi-automatic machine.

Cutting Tools.

Of recent years the subject of cutting tools, particularly with reference to the most efficient cutting angles, speeds and feeds, has been closely investigated in this country by Professor Ripper, Mr. Dempster Smith, and others. There has also been a considerable amount of experiment by the leading tool steel makers, working in collaboration with the users of such steel and with the makers of heavy machine tools. As the result of such investi-

gation and experiment, combined with improved design of machine tools, it has been found possible to obtain a production on certain machines three times that of the ordinary practice of ten years ago.

This result is due to three factors, all of which are necessary to efficiency, viz. :—

(1) Rigidity of the machine and its tool holders.

(2) A sufficient tool section to support the shearing and compression load with a reasonable overhang of the tool and to dissipate the heat generated at the tool point.

(3) Correct cutting angles varied to suit conditions.

By the employment of a fourth factor, namely, the use of two or more cutting tools simultaneously, output on certain work on

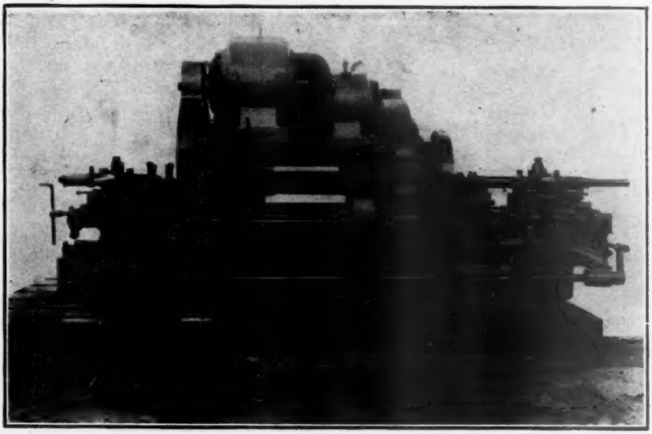


Fig. 7.—A wheel centre machine.

which it is possible to use more than one tool has been increased from four to five times what it was ten years ago. The comparison of output is made between the heavy type of machine which, up to ten years ago, was designed to employ two tools only on such work as shafting and axles, steel tyres, etc. Thus it was common practice to employ two tools only simultaneously on the rough machining of forged railway axles, and it is now found quite practicable, simply by recent improvements made in the tools, to employ as many as sixteen cutting tools simultaneously. At the same time, the power absorbed by an improved lathe is 35 h.p. with sixteen tools cutting, as compared with 18 h.p. absorbed by the previous design with two tools cutting. Observa-

tion of the time taken by the multiple cutting system shows the ratio in favour of this method to be three to one on the machining operation. An interesting example of multiple tooling is shown in fig. 9, which illustrates the tool layout for the tyre boring machine previously shown.

On the re-turning of the profile of worn tyres of railway wheels in material of 45 to 48 tons tensile, it is found quite practicable to employ three tools for the roughing operation on each tyre

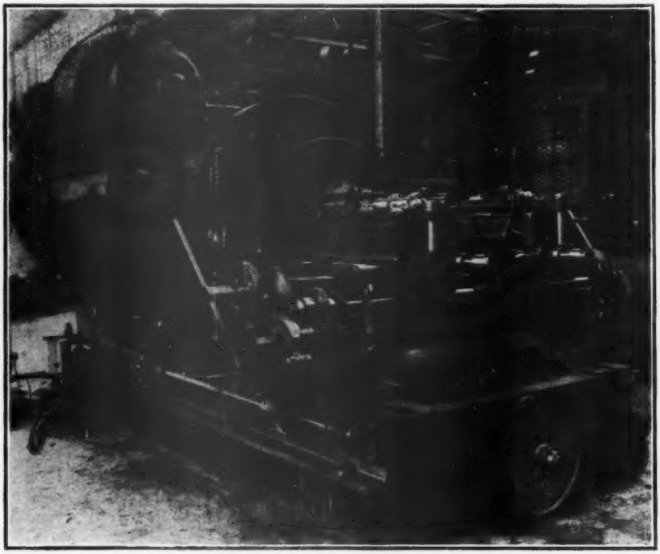


Fig. 8.—A car tyre borer.

instead of one as formerly. The actual machining time on a 3ft. 6in. diameter tyre of medium hardness is about thirteen minutes using one tool, and this time has been reduced, using three tools, to as low as four and a half minutes. This refers to a heavy cut on the profile only of the tyre and not upon the sides. The cutting tools being of improved form and the lathe of better design, it is found that the absorption of motive power has been increased by this method by only 30 per cent. (say, 23 h.p. raised to 30 h.p.), as compared with an increase in the amount of metal removed of nearly 190 per cent.

With regard to the question of cutting angles and the general form of cutting tools, experiments have been made recently in the

ordinary course of workshop production to ascertain the most suitable shape of cutting tool for use with heavy machine tools, as it is obvious that this question will bear a considerable amount of attention and investigation. A round or symmetrical cutter, viz., one in which the cutting edge describes a circle on the horizontal plane, is exhibited in order to show the extreme sharpness of the top rake angle which is possible in such a tool. It is, of course, known to some of us that cutters of a similar shape have been used occasionally during the past twenty-five years, and perhaps further back than that, for example, in cutting profiles with a profiling attachment in which two adjacent outlines are

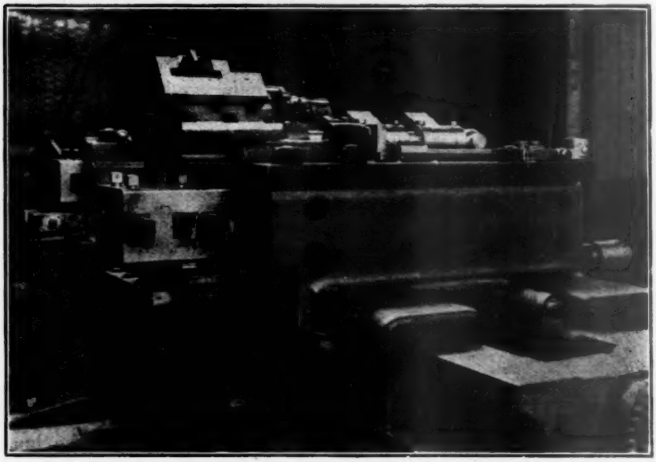


Fig. 9.—A tool layout for tyre boring machine.

joined by a radius. The problem met with in actual practice recently, however, of developing tools commensurate in strength with the machines on which they are to be employed, has made it necessary to devote more attention to the form and quality of such tools.

It is found that if this sharp circular tool is held in a sufficiently rigid support in order to eliminate as far as possible unnecessary strains, the cutting edge holds up remarkably well. It might easily be supposed from an examination of the tool that it would not be possible to feed it in deeply to reduce a diameter, and that the load on the front of the cutting edge when feeding in would snap off the thin edge, but in fact it appears that sharpness of the edge, within certain limits, rather protects the tool

from damage. For instance, the one shown can be fed into a steel forging revolving at a speed of 60ft. per minute to a depth of $\frac{3}{8}$in., and then traversed longitudinally to reduce the diameter for any ordinary length required. Since, when feeding in the tool, the line of shear traces a true spiral with the point of shear slightly in advance of the cutting edge, the sharp edge maintains its form, and an examination of the chips exhibited will show that, due to the curve of the cup of the tool, and the fact that it has been rigidly supported, there are no flats on the sheared side of the chip such as occur when the ordinary round-nosed tool is used.

Now, it should be stated that this subject of cutting tools for use with heavy machinery has been demonstrated to be of so much importance, from the point of view of the works manager, that it is worth while taking a little time to go into the question, and those of us who are concerned in quick and economical production will undoubtedly be interested in any demonstrated results. The development of the symmetrical cutter seems to the author to be a perfectly natural process of evolution. First, we have the ordinary round-nosed tool as exhibited here. This tool can only cut on a limited area of its surface, and it can only cut satisfactorily in one direction, as the provision of side rake makes negative rake on the non-cutting side. Secondly, the same class of round-nosed tool can be so shaped that its cutting edge describes a half-circle on the same horizontal plane, top rake being provided in all directions towards a central point, as shown by the model exhibited. This tool is not of an easy shape to produce or grind, although a larger cutting area is available. It has been used successfully to cut right and left as required, but has not been extensively adopted.

Thirdly, if the last-named form is developed from the half circle to a full circle as regards the cutting edge, a symmetrical cutter is produced with a continuous cutting edge on the horizontal plane raked down to a common centre. Since this tool can be rotated on a suitable shank or pivot, any desired part of its circumference can be brought into use. At the same time, being absolutely symmetrical, it can be produced in the lathe, and, the top rake being machined to a radius, it can be easily ground.

But perhaps the most interesting fact is that, owing to its symmetrical form, it can be provided with a keener cutting edge than is permissible with the rectangular section tool. Thus, if a tool is produced whose cutting edge is semi-circular, and if the same keen top rake is given to it, we find that it fails near the junction of the cutting edge with the rectangular portion. This is to be expected, and is obviously due to the unequal section. Investigation which has been made goes to show that, unless this second form of tool above described were to be produced with a

certain special contour, it would fail as mentioned, and, although it would be possible to produce such a form in the second tool, it would be difficult and uneconomical to maintain it. We can therefore substitute for it the symmetrical shape of the third form in which the uniformity of section provides keenness combined with strength.

There is little time at the disposal of the average busy works manager to investigate properly the effects of distribution of heat in cutting tools, and this important question must be left to the researches of our scientific institutions; but the sensible evidence of heating effects is that the symmetrical section dissipates such heat more readily and uniformly, and is much less liable to damage by heating than is an unsymmetrical section. In a tool on which the upper surface is concave, the chip as it is sheared follows the curve of the cup, a chip of heavy section almost filling up the area of the cup, thus transmitting its heat fairly uniformly to the whole top contour of the cutter. If therefore the curved contour or top rake is made of the correct radius for the particular class of metal to be cut, we have a more uniform distribution of heat than in the case of any of the tools of irregular section.

The exhibit shown is a round-nosed tool of ordinary shape with a keen side and top rake, and it is shown together with a symmetrical cutter. These two tools have been tested on a light cut $\frac{1}{8}$in. deep by $\frac{1}{8}$in. traverse. The speed of cutting was 115ft. per minute, using cooling liquid. A belt-driven lathe was employed. In two tests with the round-nosed tool it was found that the speed of the lathe was immediately slowed down from 115ft. to 75ft. by resistance to cutting, and that, after traversing about one foot, the tool was useless for further work without grinding. In the case of the symmetrical cutter under exactly the same conditions, the length of 12ft. was traversed and the speed of 115ft. maintained itself throughout, the tool still being good for continuous cutting at the same point of its circumference.

Results equivalent to the above are obtained with the symmetrical cutter with a fairly keen cutting edge on such material as chrome nickel forgings. On any ordinary steel material up to, say, 45 tons tensile, the cutter can be fed in easily to a depth equal to half its diameter, and traversed at that depth. The condition of the chip shows that the absence of negative rake on the tools gives a decided advantage.

THE DISCUSSION

Before declaring the meeting open for discussion, the chairman, Mr. A. Butler (Vice-President), remarked that there were a number of interesting exhibits, consisting of turning tools, chips and metal cuttings of an exceptional nature, etc., which members might like to examine. The chairman then called upon Mr. Hutchinson to open the discussion.

Mr. Hutchinson (Member of Council): The paper was so excellent and the descriptions given so full, that there is very little one can find to discuss. There is one thing which did strike me, *i.e.*, that it is very refreshing to see such illustrations of heavy English machine tools when one is always hearing of the backwardness of English manufacturers and the forwardness of others. I am sure that when one looks at some of the illustrations shown on the screen they certainly bring home to us that we are "top dogs" in the machine tool world. One very interesting point was the question of the special cutter in relation to increase in power. I should like a little more information regarding the use of such a tool and why the power was only increased 30 per cent., whereas the amount of metal that could be removed was 190 per cent. more.

Mr. Andrew: I should explain that the small increase in power is due mainly to the fact that various recent improvements in design and tooling serve two purposes, *i.e.*, they enable us to use multiple tools in the cutting of hard metal, such as tyres, and at the same time reduce the amount of power required to operate the machine itself apart from the tools.

I have given 23 h.p. as being formerly used, and this refers to the old design of lathe, against 30 h.p. as used on the recent design. The section of cut previously taken was, say, 0·250in. deep by 0·312in. traverse, equalling 0·078 cubic in., and on the same material it is now, with three tools cutting on each tyre, a combined total section of almost 0·750in. by 0·312in., or nearly 0·234 cubic in., at the same cutting speed. The comparison, therefore, is an average of 190 per cent. more metal removed against an increase in power of only 30 per cent.

Mr. Hutchinson: In the double lathes I take it that the loose headstock is moved back. It was not quite clear from the illustration what connection there was from the driving shaft on to the two headstocks. Is there any means of taking up the backlash on the gears?

Mr. Andrew: There are two driving shafts, one in front of the lathe running at high speed, geared through to a slow speed auxiliary shaft on the centre line of the machine, the auxiliary shaft carrying a pinion which gears directly into the main faceplate gear ring.

It is not necessary to take up backlash in such gears, as they are

accurately cut to give a smooth rolling contact, and no difficulty is experienced with this design in obtaining a smooth surface on the work at both headstocks, profile forming tools being used to obtain the smooth finish. The difficulty which previously existed of a certain amount of chatter at the headstock furthest from the driving end of the lathe is found to be quite overcome by the use of an auxiliary driving shaft.

Mr. Rawlings: To what degree of accuracy do you machine the loco. cylinders on the boring machines mentioned? I take it that the cylinders are about 26in. to 28in. diameter. Do you find it necessary to grind them afterwards?

Mr. Andrew: We bore the loco. cylinders to a degree of accuracy of 0·002in. on a diameter of 28in. This is considered satisfactory for loco. practice without subsequent grinding.

Mr. Rawlings: I met a case some time ago in connection with a Diesel engine liner 20in. bore, 5ft. long. It had been the firm's practice to bore it out close to size rather than to get it accurate. The finish was the main thing, and that, of course, entailed making the pistons to suit the cylinders and everything else, but by the introduction of grinding they found they could work to a limit of 0·0002in. Ground cylinders have been used on locos. The 5ft. by 20in. Diesel engine cylinder was ground up in 4 hours, removing 0·025in.

Mr. Baines: The multiple drill seems not to be recommended from the point of view of production. We thought of introducing multiple drills. What do you think of a multiple drill in a general engineering shop?

Mr. Andrew: They are used to a large extent perhaps, particularly in America, for standard electric motor parts, and in some cases in engine works at home and abroad for such work as cylinder lids and small covers. They are used extensively, too, in America for drilling motor frames and other such work where there are a number of holes to be drilled in circular or rectangular groups. The number of multiple drilling machines of this kind in use does not seem to increase. They are generally liable to get out of order easily, and there is always the difficulty of having to drive at an angle. One cannot get a sufficiently powerful drive on to each spindle to make it worth while without making the machine too expensive, the result being that in the case of large machines of this type they can hardly be made at a marketable price if they are to be thoroughly efficient. I have known several cases where they have been built to suit special conditions, and where the user has been willing to cover the cost. I refer, of course, to the large machines, not to the smaller sizes. In the case of the heavy machine it is obvious that, if designed to be efficient, it would have to do a great deal of work to make it profitable, and it is difficult to prove this in advance in all cases. The gang drill, or straight row of drill spindles, is generally found to fulfil all ordinary needs.

Mr. Rawlings: What are your opinions of the merits of a portable radial drill against the horizontal drill mentioned for boiler work?

Mr. Andrew: Both types are in use, of course. It seems to me that any type of radial drill does not lend itself readily to loco.

boiler drilling under present-day conditions where the entire shell and firebox is handled in one piece. The horizontal machine with a vertical column is specially adapted to the purpose, as the complete job is set upon a table which can be rotated and moved in and out, and the drilling spindle can be traversed up and down and across the work. It is, therefore, easy to travel, for instance, from one point to another point which may be situated diagonally from the first. Although there is only one spindle in the design shown on the screen, it is driven by a motor geared directly to it, and is therefore very efficient. There are several designs with more than one spindle.

Mr. Butler: On the newer type of cylinder boring machine I could not see from the illustration whether the outer ends of the boring bars were supported. Is it necessary to support them, and, if not, about what diameter are they for the average cylinder?

This question was answered by Mr. Andrew by means of photographs and slides. It was shown that when the machine was photographed the supports had not been advanced on to the bars, *i.e.*, the bars were shown unsupported at the outer end as they are when the cylinder casting is placed upon the travelling table.

A Member: In connection with turning wagon wheels, I believe the time was given as 14 minutes from floor to floor, but later on in the paper a turning time was quoted of 4½ minutes, which leaves 9½ minutes for loading time.

Mr. Andrew: The time quoted of 4½ minutes will be seen by reference to the context to refer to the roughing operation only. The tyre is afterwards smoothed up with a forming tool, taking another 4 minutes, leaving the balance for putting the wheels in and out of the machine.

Mr. Rawlings: Are Armstrong-Whitworth's developing the surface grinder for heavy engineering work? I have seen one or two examples of steam chest covers, etc., ground instead of planed.

Mr. Andrew: No, the company are not at present developing the surface grinder. They have recently been concentrating particularly on railway machinery and the heavy cylindrical grinder. Like other machine tool makers, they will extend their range according to what the universal tendency is, so far as they are aware of it. There are many cases like the multiple drill question, where if somebody could produce a cheap and efficient machine it would be worth while. The difficulty, however, is that the ground has not been properly explored, and machine tool makers are afraid of going too far.

We come, after all, to the commercial side of the question. If one takes up a type of machine which involves new principles, one can very easily spend thousands of pounds and find it has been superseded by somebody else working on simpler lines. I think all machine tool makers like to get the opinion of the machine tool users as to what they ought to do. They could often give the makers very good advice about the use of machines. Very frequently machine tool makers are put up against some problem, and they take it up; then it is entirely up to them to make it a success. I mean that a user very often does not want to bear any part of the burden of experimentation; the machine

tool maker must do that. That is a great drawback, as the first maker must experiment and spend the money. If he has made an error of judgment he has to pay for it, and sometimes very heavily. I have more than once seen a very heavy machine turned out and expected to do great things, and which has cost the maker a lot more than he has obtained for it. It has afterwards been found that it has not been adopted on account of first cost.

Mr. Hutchinson : I should like to propose a vote of thanks to Mr. Andrew, and to say how much we, as an Institution, appreciate his coming here and giving us a paper. I have found it very interesting and instructive, and should like to have a further discussion of the subject another evening. I have pleasure in proposing a very hearty vote of thanks to Mr. Andrew.

Mr. Baines (Messrs. W. H. Allen & Co., Ltd., Bedford) : We very much appreciate the paper we have come from Bedford to hear, and I have very great pleasure in seconding this vote of thanks.

In acknowledging the vote of thanks, Mr. Andrew suggested that with regard to questions which could not be fully answered at the meeting written communications could be made after the meeting, and he would then give his considered answer.

THE

INSTITUTION OF PRODUCTION ENGINEERS.

A GENERAL Meeting of the Institution was held at the Engineers' Club, Coventry Street, W.1, at 7.30 p.m. on Wednesday, January 21st.

The Minutes of the previous meeting were read and approved.

At this meeting Mr. H. A. Randall, of the Cambridge Instrument Co., read a paper on "Instruments and Gauges," which was illustrated by lantern slides.

The meeting concluded with a vote of thanks to the lecturer.

INSTRUMENTS AND GAUGES.

By Mr. H. A. RANDALL, of the Cambridge Instrument Co., London, S.W.1.

No doubt the war did more than anything else to bring about the general introduction of instruments into the engineering industry. Even small works to-day are using appliances of this kind which ten years ago would have been found only in the largest shops in the country. Modern conditions make it necessary for all engineers to use methods which will give increased economy and efficiency.

When the need of scientific instruments was first felt in industry, attempts were naturally made to use those of existing design; as these had been made for use under laboratory conditions in most cases, they soon failed from some cause or other. Half-hearted attempts were then made to adapt them, but this did not make matters much better, with the result that instruments generally were given a bad name, which, unfortunately, still lingers on. For some time past, however, instrument makers have been giving industrial apparatus their serious consideration, and to-day their products are sufficiently robust in construction to withstand a reasonable amount of unskilled handling, and yet provide results of the requisite accuracy.

At some point in practically all manufacturing processes, the question of temperature measurement or control has to be considered. In this particular branch, the makers of apparatus have made great strides, and there is now no reason for using the old method of judging by eye. It is proposed, however, to deal with pyrometers at the end of the paper.

The first to be considered will be the microscope lathe attachment. The production of accurate screw threads calls for some finer method of tool adjustment than is generally used. Screw tool gauges are by no means easy to apply, and in the case of internal threads the position becomes even more difficult. The microscope lathe attachment not only enables the operator to set the angle of the tool within 0 deg. 3 min., but, when cutting male threads, the cutting operation can be closely watched. Any error is magnified twenty times. The device is fixed to and moves with the slide rest of the lathe, and the microscope is fitted with

an eyepiece which can be focussed on a diaphragm ruled with three lines. Two of these lines represent the thread angle, and the third is equally inclined to the other two, as shown in fig. 1. The cross line is set parallel to the axis of the work being screwed, and the tool is set to the lines representing the thread angle.

The microscope is arranged so that it can be moved across the diameter or parallel to the axis of the work, the last-named movement being fitted with fine adjustment. The diaphragm can be ruled for Standard Whitworth or any other form of thread.

It will be seen that the use of this instrument will enable the operator to set and check the tool with much greater ease and accuracy than is possible with an ordinary screw thread gauge.

For the accurate measurement of lengths up to 40 mm. the measuring microscope can be used with advantage both in the

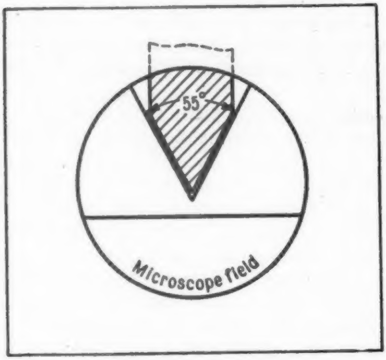


Fig. 1.—The field of the thread microscope.

workshop and laboratory. The instrument consists of a microscope clamped to a tube, which is supported in a rigid frame and can be traversed by a screw and milled head through a distance of 40 mm. Its use for measuring the diameter of the indentations made in the Brinell hardness test, as well as for measuring lengths, is familiar to production engineers and need not be described in detail.

One form of this piece of apparatus has two microscopes in place of one. Rapid and accurate comparison of lengths can be made from 50 ft. to 400 mm. on a scale against the same length on a standard scale. The instrument is precisely similar in construction to the measuring microscope, but the tube to which the two microscopes are clamped is 500 mm. long. One of the eyepieces is usually fitted with a filar micrometer eyepiece on which

the difference between the two lengths under comparison can be measured directly; this simplifies the adjustment. The substitution of telescopes for the microscopes converts the instrument into a telescope comparator for taking readings at a distance. The accuracy is independent of the distance of the object or the angle between the two telescopes. One useful application may be mentioned, namely, its use in determining the expansion of fire-bricks for muffle furnaces. Both this instrument and the measuring microscope are provided with a tripod base, when it is desired to measure vertical distances.

For determining accurately the errors of screws up to 32 mm. diameter the screw measuring machine should be used. The elements which can be determined by its use are :—

External and root diameters.
Pitch.
Effective diameter of V threads.
Inclination of V threads, as well as variations of these quantities from one part of the thread to another.

The screw under observation is held in a self-centring chuck under a microscope. Two slow motions at right angles, with micrometer readings, are provided for moving the screw. One movement enables the screw under test to receive accurately measured displacements, in a direction perpendicular to its axis, and the other gives displacements in a direction parallel to its axis. Readings can be taken directly to 0·01 mm.

The microscope through which the screw thread is viewed is carried on a casting rigidly attached to the bed of the apparatus and can be set over to right or left. The amount of inclination, which should be equal to the mean angle of the thread examined, is read by means of an arc divided in 30 minutes. The microscope can be rotated so as to bring one of the cross lines parallel to the sides of the V threads, and the angle through which it is moved is read on a divided circle.

For ordinary work an electric lamp can be used, but to ensure accuracy when measuring screws of different angles it is necessary to use a parallel beam of light, and to have means of varying the angle of incidence of the light. A special lamp in connection with a prism illuminates the screw from below, and throws a parallel beam of light up the microscope tube parallel to the optical axis. The whole arrangement can be set over to right or left to agree with the angle at which the tube is inclined.

It will be generally agreed that the manufacture of a highly accurate square by the ordinary method is as cumbersome and costly as the generation of a perfect surface plate. The self-checking square, shown in fig. 2, overcomes these difficulties.

It consists of a stiffly webbed iron casting having three

accurately machined faces. Slots are cut in the upper and lower faces through which sensitive adjustable spirit levels mounted on the under sides of these faces can be observed. The method of checking and correction depends upon the "method of reversal" as applied to spirit levels, complicated only by the presence of the vertical face. The castings are aged for at least six months before the final adjustments are made.

The surface plate on which the adjustments are made is mounted perfectly level by means of a delicate spirit level. Great care is

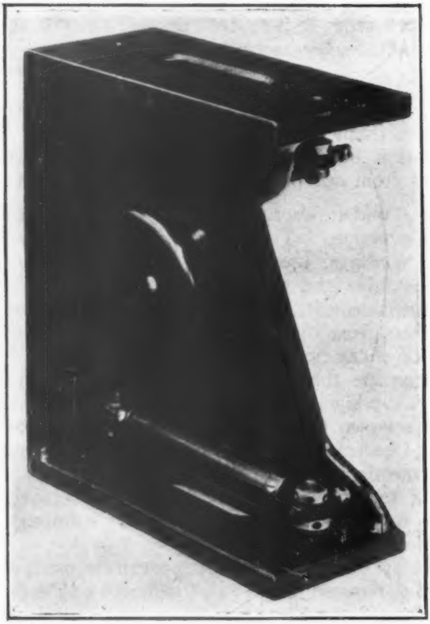


Fig. 2.—The self-checking square.

taken that this surface plate is free from vibration and rapid temperature changes. The first operation is to make the two slotted faces parallel, and the method in use is to stand the square on the surface plate with its plain face vertical and apply a spirit level to the upper slotted face. It will be seen at once from which point material has to be removed in order to make this face parallel with the lower one. As perfect accuracy is approached,

both the level and the square are changed end for end, in order to eliminate any error in the mounting of the bubble or the surface plate. When this operation is completed the levels attached to the square are adjusted to read perfectly centrally when either face is standing on the surface plate.

It may be thought that the more direct method of using a micrometer reading to 0·0001in. would be better than that described above, but extraordinary precautions would have to be taken to ensure that the temperature of the micrometer remained constant from reading to reading, as an error of 0·0001in. gives an appreciable deflection of the bubble used in the finished level. In order to make the vertical face square with the other two, an angle plate is placed upon the surface plate and, keeping the slotted faces clear of the surface plate, the vertical face is applied to the angle plate, first with one slotted face and then the other one uppermost. If the deflections of the attached levels are both in the same direction and too large to read, the surface plate is thrown out of level, in order to make the surface of the angle plate more nearly vertical, until it is found that one bubble moves towards the right and the other to the left.

An amount must then be removed from one end of the vertical edge of the square until the deflections are equal and in the same direction, or in the unlikely event of the angle plate being perfect, until each bubble remains central on reversal. The sides of the square are 130 mm. long, and as the bubbles give a deflection of 1 mm. for 5 seconds of arc, expressed in linear measure, the maximum error is 0·000315 mm. It is possible to read the bubbles to 0·5 mm., so it will be seen that any degree of commercial accuracy desired can easily be obtained. These squares require to be used with care as slight local heating will give an appreciable error.

In order to reduce local heating to a minimum, ebonite discs are fitted to the central web for holding. In the erection of machine tools a square such as this is of considerable value. By its use the parallelism of the cross slide and the table of planing machines can be checked and also the squareness of the housing. In the tool room it is of great use in checking squares, particularly as it is self-checking.

Although the ordinary tensile, compression, and bending tests still serve a very useful purpose, there is now a demand for machines for testing the fatigue-resisting qualities of metals. This demand has increased with the development of motor and aerial transport and the introduction of high-speed machinery. Repeated impact testing machines have been developed for this purpose and are no doubt familiar to production engineers. In the machine shown in fig. 3 the test piece is subjected to a continuous series of blows of relatively small force delivered alter-

nately on opposite sides of the test piece. Such a method most nearly reproduces the actual conditions of use and so gives more reliable information than can be obtained by other means.

The machine is fitted with a cone pulley so that it can be driven by a belt from a line shaft or other source of power. This pulley is keyed to a shaft which carries a crank connected to a lifting rod. The rod is supported on a roller at some point in its length, so that the circular motion imparted to the rod at the crank causes it to rock and slide on the roller. Thus an oval path is traced out by the end of the lifting rod; at this end the rod is bent at right angles so that on the up stroke it engages with and lifts a hammer head. Having reached the top of its path the rod moves forward and releases the hammer, which then falls freely on to

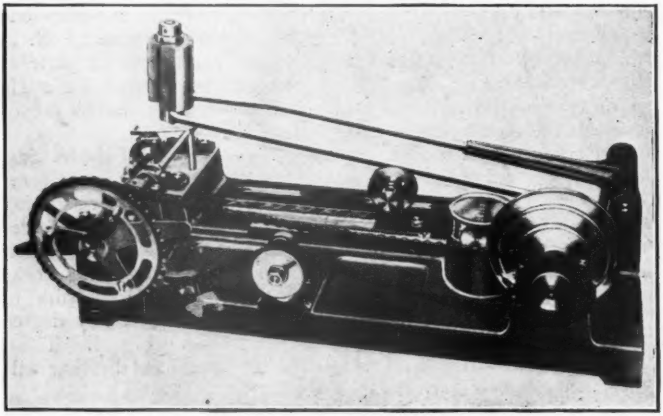


Fig. 3.—The repeated impact testing machine.

the test piece. The rate of the hammer blows can be varied from 70 to 100 per minute, whilst the height through which the hammer falls can be varied by moving the roller which supports the lifting rod along a scale which is calibrated to read directly the vertical drop of the hammer head. A maximum adjustment of 90 mm. is possible, and the test piece is usually 12 mm. diameter and has a groove turned in its centre to ensure fracture at that point.

The test piece is supported on knife edges 114 mm. apart, the hammer striking it mid-way between these knife edges. Between each blow the test piece is rotated through 180 deg., a revolution counter giving the number of blows struck, whilst a special trip gear is arranged to throw the machine out of operation as soon as the specimen is broken.

The results obtained by this machine form a reliable method of comparing the shock-resisting properties of any two steels, or the relative advantages of various heat treatments from the shock-resisting point of view.

It is not proposed to deal with the older and well-known Ewing Extensometer, but to bring to your notice an instrument which was designed to be particularly suitable for workshop use. No mirrors or microscopes are used for magnification, and although it has no delicate parts likely to get out of order, it is accurate to about one-thousandth of a millimetre under ordinary conditions of test.

The instrument is in two parts, each of which is separately attached to the test piece by hard steel conical points which are driven gently into punch marks made in the specimen and clamped into position by milled heads. In order to get these centre punch marks in the correct position so that the instrument shall be properly located on the test piece, a special marking off tool is provided. The lower half of the appliance carries a micrometer screw fitted with a hardened steel point and a divided head. It also carries a vertical arm at the top of which is a hardened steel knife edge which acts as a fulcrum for the upper and lower parts of the instrument. A nickel-plated flexible steel tongue forming a continuation of the upper half projects over the micrometer point. This tongue acts as a lever magnifying the extension of the specimen so that the movement of the tongue to and away from the point is five times the actual extension of the specimen.

When taking a reading the thin steel is caused to vibrate, and the divided head is then turned until the point just touches the hard steel knife edge on the tongue as it vibrates to and fro. This simple method has proved a most delicate way of setting the micrometer screw, as the noise produced and the fact that the vibrations are so quickly damped out indicate to 1/1,000 mm. the instant the screw touches the tongue. As the load is applied a second reading is taken, and the difference in the readings gives the extension of the test piece. No damage can be done by advancing the screw too far. This instrument can be used on test pieces up to 20 mm. diameter.

All those who have superintended the erection of large planing and milling machines know the many difficulties encountered in the final alignment of the machine. By comparing the straightness of the bed under test, however, with that of a fine wire stretched horizontally between two clamps secured to the ends of the bed, the operation is greatly simplified. The clamps are arranged so that the wire can be accurately adjusted in the transverse and vertical directions. This wire is viewed through the microscope, which is mounted vertically above it on a bracket

or other support fitting geometrically on the guides it is desired to test, the complete arrangement being shown in fig. 4. As the bracket is traversed along the bed any want of alignment is at once apparent, since the microscope is fitted with a micrometer eyepiece, one division of the scale corresponding to 0·0005in..

Two examples of the use of this instrument may be quoted. In the first case the tester was used on the bed of a 34ft. planing machine used for planing grinding machine bodies. The error in alignment was found to be as much as 0·0115in. The body was then sprung until the error did not exceed 0·00125in. This is as

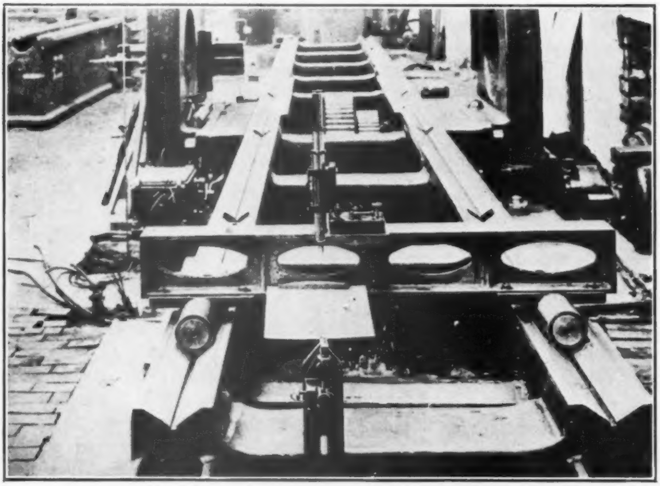


Fig. 4.—An interesting arrangement for checking alignment.

near rectilinearity as it is possible to machine a grinding machine body, as the distortion in the body itself after machining would be greater than the errors in the planing machine.

The second example is the case of a grinding machine body 54ft. long made up of a 30ft. centre piece and two end portions of 12ft. each. When the three pieces were joined up the maximum error was found to be 0·009in. By using the alignment tester it was at once evident where to start correction, and in one day the three pieces were lined up to within 0·0025in. of a straight line.

For checking the level of supports on which turbine rotors are placed when being tested for static balance or for levelling

machine tool beds, the levelling micrometer shown in fig. 5 may be employed. An H-type girder is fitted with metal plates across the ends, and the upper half thus becomes a trough, which is mounted on supports or feet parallel to the bed of the machine under test. The feet are arranged to give three-point support to the girder. The trough is then filled with oil which provides a perfectly horizontal surface, and the micrometer, which is supported on three fixed toes, rests on the table of the machine and is placed so that the point of the screw is above the surface of the oil in the trough.

Next, the micrometer head is turned until the point of the screw just touches the surface of the oil and a reading is taken.

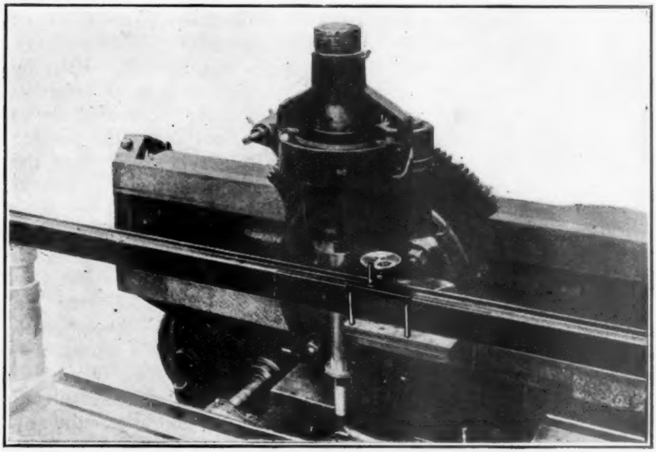


Fig. 5.—A levelling micrometer for machine tool beds.

Similar readings taken at other points along the bed will show any variation in the level. The adjustment of the screw so that the point just touches the surface of the oil can be made with great accuracy. One of the toes supporting the micrometer is provided with a lever which can be depressed, thus tilting the instrument and so breaking the contact between the point of the screw and the surface of the oil. Without this device it might be necessary to turn the micrometer head through a whole revolution; when the lever is released the micrometer returns to its original level. Small metal rings are provided for placing in the oil trough, so that they just project above the surface of the oil.

The readings are taken in the centre of these rings so that any waves are prevented from reaching the screw point.

During the manufacture of large forgings and steel ingots severe stresses are often set up, which sometimes reach a value sufficient to cause rupture of the material. When the fracture takes place it is usually accompanied by a ringing noise which is best described by the word "clink." In the past this noise has been the only evidence of such rupture, and if it occurred during the night a large amount of money might be spent on machining or the forging might even get into commission without the flaw being detected.

It is in order to avert this danger that the "Clink Detector" has been developed. The instrument is attached to the forging during the heating and cooling processes, and gives an autographic record of any shocks which may have occurred. It is sensitive enough to record ordinary hammer blows, which is taken advantage of to prove that the apparatus is in working order, by arranging for someone to strike the forging at regular intervals during the time the record is being made. If the record shows any shocks not accounted for by these hammer blows the forging is rejected. The recorder is of the writing type, and when the detector is set up on the forging, sufficient current is passed through it and the recorder, which is in series, to give approximately three-quarters of the full scale deflection to the pen. Any shock which occurs in the forging will cause the detector to break the electrical connection and thus make a mark on the record.

The detector consists of a steel bar to which is fitted an adjustable platinum contact point. This makes contact with another point which is carried on a flat steel spring supported horizontally from the steel bar. The spring is fitted with a brass weight immediately under the contact point and is insulated from the steel supporting bar. Under normal conditions the two platinum points just make contact and so let the current pass, but owing to the inertia of the weight the occurrence of a clink causes them to open and so break the circuit, which brings the recorder pen to zero. As the current is only cut off for a moment the record pen returns to its normal position.

In machine shops and printing works using automatic or semi-automatic machines it is sometimes desirable to have a check on the idle periods; in such cases the machine running recorder can be used. This instrument is designed to record the number and duration of stoppages on a number of machines, usually fifty.

Each machine is fitted with an automatic contact maker which closes when the machine stops. The contact on each machine is connected up to a separate contact stud on the recorder, a common battery and return wire being used for all the machines. These

contact studs are arranged on some three-quarters of the circumference of a circle on a plate in the recorder. An arm rotating about the centre of this circle carries a contact brush, which runs over the studs, the arm being mounted on to the top of the main spindle. This is driven through a double worm reduction gear from a small electric motor, and the gearing is such that it makes one revolution in six seconds.

The motor is controlled by a mechanical governor so that it runs at a constant speed, and the recording arm is mounted on a spindle parallel to the main spindle, on which is fixed a cam which rocks the recording arm from right to left in $4\frac{1}{2}$ seconds, while the brush passes over the fifty contact studs. It is returned from left to right in $1\frac{1}{2}$ seconds, while the brush runs over the gap in the circle of studs. A roller is fixed to the arm and is kept in contact with the cam by means of a helical spring. The paper is driven by means of a ratchet movement, which is also operated from the main spindle, a suitable reduction gear giving a forward feed of 6in. per hour. This speed is just sufficient to enable each stroke of the arm to appear as an independent line on the chart. The records are made on a continuous paper chart, which is drawn over a brass table; the paper being gripped between a driving roller and a small milled wheel. This is pressed on to the paper and is carried in a frame which rotates on an axis and is held up against the roller by means of a helical spring.

The recording arm marks the paper in the following manner: At the end of the arm is carried an electro-magnet, the armature of which is pivoted and carries a very light frame, in which is mounted a small sharp-edged wheel. When no current is passing through the electro-magnet the wheel is out of contact with the paper, but when energised by the contact brush passing over a live contact stud the attractive force on the armature presses the wheel into contact with the paper. On a separate spindle is carried an inking roller which rests by gravity on the upper edge of this wheel. This is impregnated with ink to last a considerable time, but a new inked roller can be put in place in a few seconds.

Considering, therefore, our paper to be divided into fifty columns, each $\frac{1}{10}$in. wide, the action of the machine is as follows: If none of the contacts is energised because all the machines are in operation, the inking roller does not touch the chart, but when one of the circuits is completed by the stoppage of one of the machines, then the inking roller proceeds to black in the corresponding column, making a series of lines, each $\frac{1}{10}$in. long across the paper, but all parallel and practically joining up to make a continuous black column, the length of which is proportional to the time during which the machine is stopped.

Two additional contacts, which are always energised, are fitted,

one at each end of the fifty main contacts, in order that the column at each end of the record shall always be blacked in, in order to draw margins from which to measure the number of the machines.

The charts are not graduated, but an engraved celluloid scale, dividing the chart width into fifty equal portions and showing the time scale, is applied to the record on the chart, when it is possible to see which machine it is that has stopped, and the duration of the stoppage.

A piece of apparatus in the same class as the machine running recorder is the Recording Counter. This instrument records the time of each tip on one or more automatic weighing machines and so serves to check the regularity of working. A number of other uses will at once present themselves to the practical man. The instrument is contained in a pear-shaped case. Charts $9\frac{1}{2}$in. in diameter can be arranged to revolve once in twenty-four hours or in twelve hours as desired. Two terminals on the recorder case enable electrical connection to be made with a contact maker mounted on the machine. Each time this contact maker is closed, a current passes through the circuit, momentarily causing the instrument pen to make a short mark on the circular chart. In order to facilitate counting, these marks are arranged in groups of five.

A novel method of recording is employed for the following instruments. The records are not dependent upon optical or photographic methods for their production, but are obtained by direct mechanical means, being recorded upon transparent celluloid. This material when acted upon by a suitable stylus is susceptible to slight deformation having such optical characteristics as to render any point on an enlarged image of a diagram readable to a high order of accuracy. The records are permanent, accurate, and can withstand the worst conditions of dirt and damp without special precautions. They appear as shown in fig. 6, and are immediately available for examination and measurement by means of a microscope. The friction of the stylus has been found to introduce no significant errors, and as the mechanical magnification is not large the inertia effects are reduced to a minimum.

The first of these instruments is the stress recorder, which has been designed to enable stress diagrams to be taken of the smallest members of a bridge. There are several stress recorders in use giving good results, but they have a very limited application due to their great length and the photographic methods of recording employed. The base length of the stress recorder should be small, so that it can be placed on very small members, which enables the engineer to obtain stress records of all parts of a structure.

For accurately measuring the vibrations of machine tools or roads, bridges, and buildings an instrument working on similar principles to a seismograph for recording vertical movements is used. The "Vibrograph," as the instrument is called, consists of a stand which, when placed upon the ground or any structure, is pivoted to the stand upon knife-edges. Due to its own inertia, the weight tends to remain at rest in space. Small vertical vibrations of the instrument, therefore, cause the lever to execute corresponding small rocking movements. These movements are magnified by an arm attached to the lever, which records upon a celluloid strip by a stylus carried at the extremity of the arm. The celluloid is moved past the stylus by means of a clockwork mechanism, the speed of which can be controlled within wide limits. An independent zero line which is also used for time recording is traced on the inner face of the celluloid strip.

When recording small vibrations a large heavy weight is used mounted so that the instrument magnifies the actual vibrations

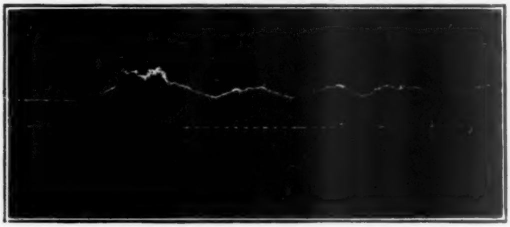


Fig. 6.—A typical record on celluloid.

fifteen times. By adjustment of a spring somewhat larger vibrations can be recorded.

When it is required to record vibrations of considerable amplitude, the large weight is removed and replaced by an arm carrying a smaller weight, which is adjustable in position along the arm. This enables unmagnified records, or any reduction between 1 : 1 and 1 : 2 to be drawn. This adjustment is of particular value when measuring vibrations which are nearly equal to the natural period of the instrument, since a slight movement of the weight will alter the period. The records will stand considerable magnification, and by this means it is possible to obtain a total magnification of about 500.

The last instrument to be described using "the stylus on celluloid" method of recording is the Micro-Indicator. This is intended for taking diagrams from high speed internal combustion engines. The instrument is in two parts, the indicator proper

and the automatic switch, which is required to prevent the overlapping of diagrams. The indicator works on the usual cylinder and piston principle. A cylinder of hard stainless steel is used with a piston and rod cut from the solid. The pressure spring used is of the flat leaf type, the movement of the indicator piston being transmitted directly to it; backlash is eliminated by means of a second spring suitably arranged.

The pressure spring carries a light arm, to the end of which is fixed the stylus which records on a celluloid disc carried on the cylindrical surface of a drum. Ten diagrams can be taken on one disc. This disc can be rotated, so as to present a fresh portion to the stylus by means of a pawl which engages with notches cut in its periphery, the pawl being controlled by a Bowden wire push switch situated close to the driver's seat. The drum on which the disc is mounted is given a reciprocating motion about its axis by means of a light steel tape which is attached to the crank or some other suitable part of the engine. Normally, the stylus is not in contact with the celluloid disc, but when the Bowden switch is depressed to rotate the disc, an electro-magnet on the indicator is energised which attracts one end of the arm carrying the stylus, thus bringing the stylus against the disc.

The automatic switch carries a worm driven at approximately engine speed. When the Bowden wire push switch is depressed as referred to above it closes an electric circuit through a magnet in the switch. This magnet actuates a simple escapement which allows a spring-controlled pivoted arm to come into such a position that, when the magnet is demagnetised on the release of the Bowden wire, a pin on the arm engages with the rotating worm, which draws the arm over. As this arm moves over it first closes and afterwards breaks the circuit of the magnet situated on the indicator. A screw control enables the time between the make and break of this circuit to synchronise with one complete engine-cycle, thus preventing overlapping of the diagrams. When the circuit is broken a spring draws the stylus away from the celluloid disc. The diagrams drawn are approximately 3 mm. long by 2·5 mm. high. A light and portable microscope fitted with a graticule is provided so that the diagrams can be immediately examined and the M.E.P. calculated without the necessity of photographic enlargement.

It is frequently of great importance to ascertain by direct measurement the torsion of a shaft or the horse-power transmitted, one of the most important examples being the power delivered to the propeller of a ship. For this purpose the Torsion Meter may be used. The Torsion Meter is a transmission type instrument, and can therefore be applied to the propeller shaft and readings taken under working conditions. The apparatus is not large, so it can easily be placed in the shaft tunnel on a portion of the shaft where the distance between a coupling and plummer

block is not less than 4ft. The indicator can be placed in the engine room, and if required can be duplicated. If desired, a permanent record can be obtained by means of a Duddell Oscillograph. The principle on which the instrument operates is as follows :—

The actual instantaneous torsion of the shaft is converted into a rapidly alternating electrical current, each of the peaks of the current curve being proportional to the instantaneous torque at the corresponding time. If it is only required to indicate the torque, an ammeter calibrated to give direct readings of the mean integrated torque is used. The construction of the instrument may be briefly described as follows :—

A suitably shaped saddle piece is fixed to the shaft and carries a U-shaped laminated magnet core on which is mounted a winding. A second saddle piece is fixed to the shaft three or four feet away from the first, and carries a tube which extends (concentric with the shaft) to the first saddle, where it is suitably supported, with freedom to turn on the shaft; at this free end it carries a U-shaped armature similar to that on the first saddle. An alternating current is supplied to the windings of the first magnet from a generator which gives an electro-motive force bearing a constant ratio to the frequency. The second armature is situated close to the free ends of the magnet core on the first saddle. A magnetic circuit is thus set up through the armature and core, and the density of the flux will depend on the length of the air gap between the two armatures. This length is determined by the torsion to which the shaft is subjected. By suitably designing the magnets and the accessories the current will be proportional to the length of the air gap, and hence to the torsion of the shaft between the two saddle pieces, and the measure of the current will give a measure of the torque.

By having two sets of magnets and armatures, facing in opposite directions mounted at 180° apart, errors due to bending of the shaft are eliminated. If it is desired that the instrument shall measure power instead of torque, the source of current is so arranged that the current is proportional to the product of the speed of the shaft and the torsional displacement.

Temperature measurement plays such a large part in modern engineering processes that it is necessary for the production engineer to be conversant with the various methods and instruments employed. Often when a temperature measuring outfit is condemned as being unreliable, it is found that the particular type installed is unsuitable for the work or conditions. Temperature measuring instruments may be roughly divided into four classes :—

(1) The expansion thermometer.
(2) The thermo-electric pyrometer.
(3) The resistance thermometer.
(4) The optical and radiation pyrometer.

The first of these includes the mercury-in-glass, the vapour pressure, and the mercury-in-steel thermometers. Modern improvements, such as the introduction of an inert gas under pressure above the column of mercury, make it possible to use the mercury-in-glass thermometers for temperatures as high as 1,000° F. or 540° C. Glass thermometers are now provided with lens fronts and an enlargement at the top of the capillary to prevent breakage in case the thermometer is overheated. They can be obtained in various ranges and patterns suitably mounted for works use.

Various kinds of mechanical thermometers have been designed to replace the mercury-in-glass thermometers because of their many drawbacks, such as difficulty of reading and risk of breakage. The instrument which has been generally adopted is the mercury-in-steel type. This thermometer consists of a steel bulb to which a steel capillary tube is attached, this being connected to a form of Bourdon pressure gauge. The bulb and capillary are filled with mercury under pressure, and the system hermetically sealed. The hand is attached through a simple mechanism to the pressure gauge, and moves over a scale, or, if it is required to record the temperatures, a pen is fitted which records on a circular chart rotated by clockwork. The bulbs of these thermometers are made in various patterns to suit different applications. The length of the capillary may be made as much as 50ft.

In order that this type of instrument shall be accurate, it is necessary to make the effective diameter of the capillary as small as possible. The dial is compensated for changes in temperature by means of a bimetallic spiral. These instruments have a range between $-40°$ C. and 540° C. Sundry attachments can be fitted, such as an electric bell to ring when any predetermined temperature is reached, or a pointer to show the maximum temperature reached since the last setting.

Thermometers of this type are being used on core stoves, annealing stoves, heating and ventilating systems, and power plants. They are very robust, and the only part likely to be broken, viz., the glass window, can be replaced for a few pence.

Useful as the mechanical thermometer is, it is evident that its temperature range is limited, and also that in many cases it is necessary to transmit the readings more than 50ft. When higher temperatures are to be measured, such as in muffle furnaces, it is necessary to employ the thermo-electric pyrometer in one or other of its many forms.

The thermo-electric pyrometer depends for its action on the thermo-electric forces set up when the junction of two dissimilar metals is heated. A complete outfit consists of a thermo-couple, a galvanometer (either in the form of an indicator or recorder), and the necessary leads.

It is worth while to master the simple theory of this instrument.

The simplest form of circuit would be that in which two wires of dissimilar metal are joined together at each end, one joint being heated and the other kept cool. A current will flow round this circuit, but there will be no external indication of the fact. It is usual to refer to the heated end of such a circuit as the "hot junction" and the other end as the "cold junction."

By joining the ends of the wire at the cold junction to the terminals of a galvanometer, we shall be able to obtain an indication of the E.M.F. set up when the "hot junction" is heated. This is the simplest form of thermo-electric pyrometer.

If the metals comprising the thermo-couple have been chosen correctly, the apparatus may now be calibrated. With the hot and cold junctions at known temperatures, the E.M.F. flowing through the circuit will have a particular value. The deflection of the galvanometer can, therefore, be made to show the temperature of the hot junction.

In actual use the thermo-couple may not be immersed to the same depth in the source of heat as when the calibration took place, also the galvanometer may not be at the same temperature. These changes will cause the electric resistance of the system to change so much that it is necessary to introduce a ballasting resistance. This resistance is made of a material which does not change its electrical resistance with change in temperature. By the aid of this ballasting resistance, the total resistance of the circuit can be made so large in comparison with the rest of the circuit that any change in those other resistances is negligible.

So far, we have considered the thermo-couple wires as being joined directly on to the galvanometer terminals. If the distance between the hot junction and the galvanometer is great, this would be very expensive, especially when using rare metal couples, to measure high temperatures. It is usual, therefore, to use a short thermo-couple and connect its cold junction to the indicator by means of twin copper cable. The use of a short thermo-couple introduces another difficulty. The cold junction is then close to the hot junction, and will vary in temperature. This difficulty can be overcome by the use of compensating leads, which are made of materials having the same thermo-electric properties as the thermo-couple. The cold junction is, therefore, removed from the head of the thermo-couple to the end of the compensating leads where the temperature is constant or some form of cold junction control is provided. This cold junction control may consist of a Dewar flask filled with oil, into which the cold junction of the thermo-couple, or the compensating leads, are placed; the point at which the copper leads join the couple being placed near the bottom of the flask. It will be found that the temperature inside the flask will not vary more than two or three degrees, although the outside atmosphere may change 20° or 30° C.

Thermo-couples are made of various metals, and are divided into two main classes :—

Base metal and
Rare metal.

Base metal couples are of two kinds, those consisting of Titan alloy wires for working temperatures up to 1,100° C., and iron-constantan wires for temperatures up to 800° C. Rare metal couples can be used for average working temperatures as high as 1,250° C., and occasional use as high as 1,400° C. The base metal couples, of course, cost much less than the rare metal couples, but the last-named are often cheaper in the long run, as they usually have a longer life.

For all ordinary commercial work it is necessary to protect the thermo-couple as fully as possible; this has led to the development of a large number of patterns, each suitable for some particular application. Amongst these are the following :—

Small muffle pattern.
Laboratory pattern.
Commercial pattern (fire-clay tube).
Blast furnace pattern (watertight head).
Plain stem pattern.
Screwed pattern.
Molten metal pattern.
Contact thermo-couple.

The material used for the protecting tube has to be chosen with great care. For annealing furnaces calorised steel and nichrome will both be found to give good service. Fire-clay tubes can be used for the above furnaces, and also for case-hardening if they are properly protected against mechanical damage.

Many types of indicators are in common use. For laboratory purposes the single-point portable indicator is most useful, but in the shops a wall type instrument is generally to be preferred. This can be either single- or multi-point. The modern practice with multi-point outfits is to enclose the switch gear in a dustproof case so as to ensure proper electrical contact.

When a permanent record is required, the indicating galvanometer is replaced by a recorder, or the two may be used together. A recording galvanometer, known as the Thread Recorder, is shown in fig. 7. In this instrument a chopper bar drops every half-minute and presses a thread impregnated with ink between the galvanometer pointer and a clock-driven chart. A record is thus made in a series of dots. The impregnated thread only requires renewal at long intervals. These recorders can be made to take any number of points up to six on the same chart. When occasional records are required from a number of points, but all need not be connected to the recorder at the same time, a plug selector

switchboard may be fitted so that any of the thermo-couples up to the maximum number which the recorder can accommodate can be connected to the recorder at will.

In some heat-treatment processes, although it is necessary to record the whole process, yet the temperature over some particular part of the range is of special interest; in such cases a scale control board can be fitted so as to give a more open record to that part of the range. By this means much clearer indications of small changes are given, and, furthermore, any errors which may be introduced due to change in resistance of the thermo-couple, leads, etc., are practically eliminated.

Thermo-electric pyrometers are usually fitted with pivoted galva-

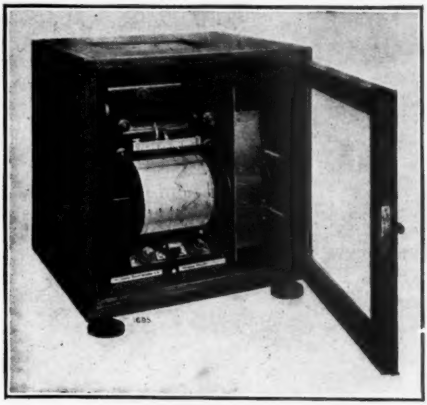


Fig. 7.—The thread recorder.

nometers, but when great accuracy is required, totally suspended instruments are used.

Engineers who are about to fit temperature control apparatus to their furnaces will find a number of types on the market, but most of these will be of American origin, more attention having been given to the subject over there than on this side. The firm with which the author is engaged have, however, been interested in the subject for the last twenty years, and are now using with great success the apparatus designed by Mr. W. H. Apthorpe.

This type of apparatus can be applied to control any temperature from the lowest which can be measured by resistance thermometers, to the highest that can be measured by the total radiation pyrometer. For the control of a gas muffle furnace the outfit consists of a thermo-couple, galvanometer, special gas valve (as

shown in fig. 8), and the necessary leads. The thermo-couple requires no special mention. The galvanometer is of the high-resistance double-pivoted type, and the pointer, which moves over a scale in the usual way, carries at its extremity two thermo-couples (arranged differentially) which are connected electrically with a moving coil relay. A small electric heater mounted on an arm is set to the point on the scale at which it is desired to control this temperature.

When this temperature is reached, the first thermo-couple on the pointer is brought opposite the heater, and, being heated, an electro-motive force is set up which tends for a moment to throw

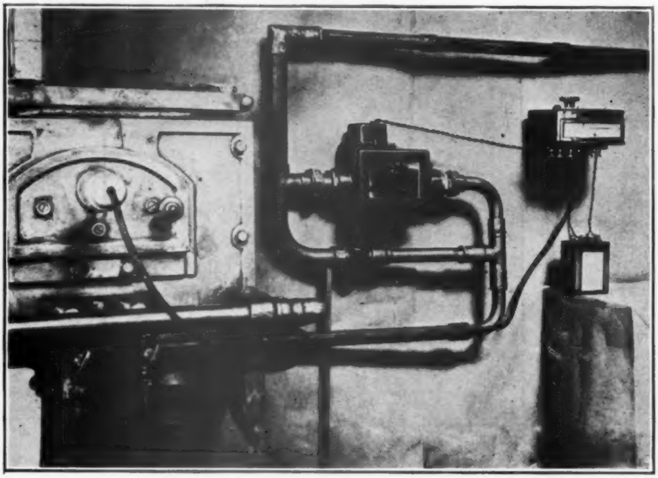


Fig. 8.—Equipment for controlling gas furnaces.

the relay arm away from the contact which it will eventually close. As the furnace continues to rise in temperature, the galvanometer pointer continues to move forward until the second thermo-couple comes opposite the heater. The electro-motive force generated by this couple actuates the relay, which shuts off the gas supply to the furnace, and the furnace begins to cool down. In response to the cooling of the furnace, the galvanometer pointer moves down the scale, and, as the first thermo-couple passes the heater, an electro-motive force is set up which helps to break the contact in the relay circuit, in case the contact should be sticking.

The gas valve used for low-pressure work is of the balanced double beat type. The gas enters the centre chamber and passes

through the top and bottom valves into the main chamber. The disc valves are mounted on a spindle suspended from one end of a horizontal bar, which is pivoted at its centre, and carries at its other end a soft iron armature which is just below the pole pieces of an electric magnet. Normally, the weight of the discs and spindle is balanced by a spring, and the valve is open. When the electro-magnet is energised (by the relay on the galvanometer) it attracts the armature, and so closes the valve. This valve is by-passed by a cock so that the amount of gas it regulates can be adjusted to any proportion of the total. For valves up to 2in. diameter, the small relay contained in the galvanometer case is sufficient, but for larger valves an additional relay must be installed. The success of a control outfit often depends entirely upon the trustworthiness and quickness of the relay.

The type found to be most suitable for this work is the Rocking Mercury Relay. This consists of a glass tube with two depressions on its lower side, into which are fused platinum contact wires. After a large globule of mercury has been placed in the tube, it is exhausted and then filled with nitrogen gas. The tube is fixed to a rocking arm which is governed by a spring and an electro-magnet. Normally, the spring tilts the arm so that all the mercury, except for a small quantity caught in the depressions, flows to one end of the tube. As there is then no metallic contact between the two platinum points, no current can flow. When, however, the electro-magnet is energised, it draws down the arm into the horizontal position, and the mercury flows along and closes the circuit between the two contact points. This relay, which can be arranged to work on D.C. or A.C., will break 5 amps. at 200 volts, which provides ample power to operate a valve; or, in the case of an electrically heated furnace, the switch mechanism.

When the gas supply is at a pressure above 10 lb. per square inch, and where high-pressure steam has to be controlled, a special relay which is fitted direct on to a screw-down valve is employed.

If the temperature to be controlled does not exceed 540° C., the mercury-in-steel thermometer fitted with an adjustable contact which can be set at any point on the scale can be used. When the thermometer pointer reaches the contact, an electrical circuit is closed which operates the gas valve or other mechanism. As soon as the temperature falls, the pointer moves away from the contact and the circuit is broken.

It will be seen that these controls can be applied to gas or electric furnaces or steam-heated chambers, and in most cases it is possible to maintain the temperature within 0·5 per cent.

Another electrical system of temperature measurement is the resistance method. In this method, the change in resistance of a wire (usually of platinum) on heating is employed as a means of measuring the temperature. Electrical resistances can be measured

with great accuracy, and the method has become the most accurate for determining temperature. The thermometer usually consists of a platinum wire 0·008in. dia. wound on a mica frame if high temperatures are to be measured or on a porcelain cylinder when dealing with lower temperatures. This coil is connected by silver or platinum leads to the terminals in the thermometer head. For ordinary commercial work, the deflection method is found to answer very well, but when greater accuracy is required, the null method is used. In the deflectional method the thermometer is placed as the fourth arm of a Wheatstone bridge, the other three arms being fixed resistances. The material used in the construction of these other arms does not change in resistance with change in temperature.

Current is supplied to the system by means of an accumulator. The values of the resistances of the coils are so chosen that at the commencing temperature of the range of the indicator no current flows through the galvanometer. Any change in the resistance of the thermometer, due to change in its temperature, will cause a corresponding current to flow through the galvanometer and so deflect the pointer, which moves over a scale calibrated in degrees of temperature.

A number of thermometers can be connected to one indicator, the effect of varying lengths of leads being eliminated by inserting in each thermometer circuit a balancing coil to bring the resistance of each circuit up to a definite value. Indicating, recording, or combined indicating and recording outfits of this type of thermometer are working in various industries and in large public buildings. One very common application is for measuring the temperatures on power plants.

Temperatures between minus 330 deg. F. and plus 1,000 deg. F. can be indicated or recorded with great accuracy, and as the instruments are calibrated for the working range only a very open scale is obtained.

The platinum resistance method can be used for temperatures as high as 1,200 deg. C. when greater accuracy than can be obtained with the thermo-electric method is required. Special care, however, has to be taken in the manufacture of the thermometers and the null method of measurement is used. Instead of using two-way leads to connect the thermometer to the bridge as described above, four-way leads are required. Two of these leads are connected in the usual way, but the other two are connected into the other side of the bridge, and their other ends joined together just above the thermometer coil, or bulb as it is termed. By this means, any changes in the leads owing to changes in their temperature must affect both sides of the bridge alike, and the balance point of the system will remain unchanged. As the method is a null one the readings are independent of the

voltage of the battery. In the Callender Recorder which is used, the method of automatically balancing the bridge is by means of two clockwork motors, one or other of which is set in motion depending upon the direction in which the galvanometer needle is deflected.

Consider what happens when the thermometer is increased in temperature. The galvanometer needle will swing to the right, and in so doing releases the magnetic brake of the right-hand motor. This motor drives through suitable gearing a rider working on the bridge wire towards the right, until the resistances of the two sides of the bridge are in balance. The galvanometer needle will then return to the null position, and in so doing will apply the brake to the motor again, and consequently stop the excursion of the rider. This instrument is very accurate and is able to follow very rapid changes. As a large power can be used to move the rider to which the pointer or recording pen is attached the instrument can be made to give a continuous line record. This instrument has been extensively used to measure the hot blast temperature on blast furnaces.

For the direct measurement of the radiation from furnaces, the Callender-Bone-Yates Bolometer can be used. The receiving portion consists of two exactly similar flat coils of platinum wire, wound on mica plates and mounted on the two ends of a cylindrical support. The platinum coils are blackened to secure more complete absorption of the radiation, and caps are provided for the two ends of the cylinder, so that either coil, or both, may be shielded from radiation. The central portion of the cylinder is made hollow and provided with inlet and outlet tubes so that a stream of water may be passed through for the purpose of maintaining a uniform temperature. The two platinum coils are connected to form two arms of a Wheatstone Bridge, the ratio arms of the bridge and the galvanometer being contained within the case of the portable indicating instrument. Since the two platinum coils are exactly similar, the galvanometer, which is a pivoted moving coil instrument with pointer, will be undeflected when neither of the coils is exposed to radiation. The rise in temperature of either coil due to radiation falling upon it will throw the bridge out of balance and cause a deflection of the galvanometer. The instrument is calibrated to read directly in calories, the range being 0-30 kilocalories per square foot per hour. Full scale deflection corresponds to a rise in temperature of about 13 deg. C. on the exposed side.

To obtain higher ranges, provision is made for cutting out resistance in definite steps from the arm of the bridge in which the exposed coil of the bolometer is connected. The resistance which is cut out is equal to the increase in resistance of the bolometer coil which is necessary to give full scale deflection. When

this resistance is taken out the indicator will therefore remain undeflected until 30 kilocalories per square foot per hour is reached, and the range will consequently be increased to 30-60 kilocalories per square foot per hour. Similarly, by taking out more resistance, ranges of 60-90 and 90-120 kilocalories per square foot per hour can be obtained. Terminals on the side of the indicator case allow for the adjustment of the range.

A 2-volt accumulator provides the current for the bridge circuit. In order that the same deflection shall always be produced by a definite change in the resistance of one of the coils it is necessary

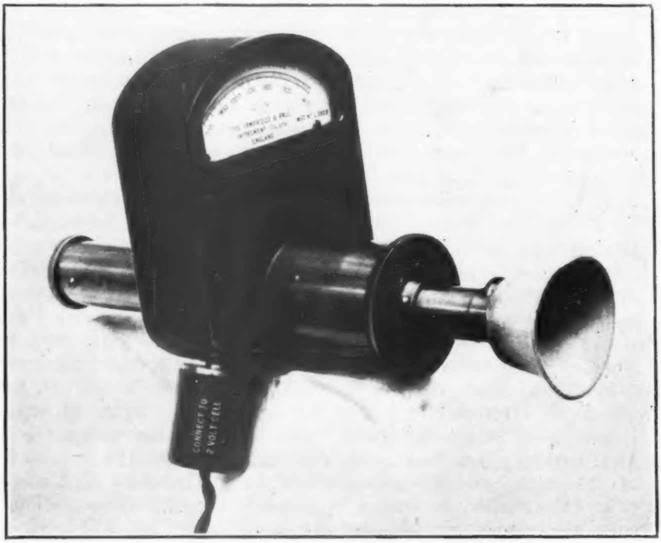


Fig. 9.—The disappearing filament pyrometer.

that the current should be constant. To ascertain whether this is the case the indicator can be connected at intervals to a test circuit, when the pointer should be deflected to a definite mark at the end of the scale. Provision is made for adjusting the current until this is the case.

Both thermo-electric pyrometers and resistance thermometers have a distinct upper limit of temperature beyond which they should not be used. In the case of the resistance thermometer, the mica frame on which the platinum coil is wound begins to disintegrate if taken above 1,200 deg. C. With thermo-electric

pyrometers the upper limit is fixed by the protecting tubes. The materials employed in their construction becomes very weak and porous at high temperatures.

It will be seen that for measuring these high temperatures it is necessary to employ some method whereby the instrument does not come into direct contact with the hot body. Many methods have been used which depend upon the operator's sense of colour. It is not at all unusual for two persons to obtain results differing as much as 100 deg. C. when using this type of pyrometer. To overcome this defect several instruments have been introduced, the latest and most simple of these being the disappearing filament pyrometer, shown in fig. 9.

In this instrument an image of the body whose temperature it is required to measure is formed by a lens on the plane of the filament of a small electric lamp. This image and filament are viewed through a second lens. By adjusting the current passing through the lamp the tip of the filament can be brought to the

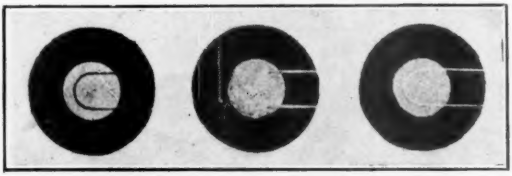


Fig. 10.—The field of the disappearing filament pyrometer.

same brightness as the hot body, when it merges into the background, and cannot be distinguished. The appearance of the filament when using the pyrometer on a furnace is shown in fig. 10.

If the current is not sufficient the filament appears as a black line on a bright background, but if too much current is flowing the filament shows up as a bright line on a darker background. When the rheostat controlling the current is correctly set the field of view appears as in the central illustration. The temperature is read on the ammeter scale, which can, of course, be calibrated either in Fahrenheit or Centigrade. As these pyrometers were first made they had a very contracted scale, and suffered from the grave disadvantage that if the lamp were broken it was necessary to return the instrument to the makers to have a new lamp fitted and a new scale calibrated to suit the new lamp.

One method of overcoming this disadvantage is by using a double coil galvanometer wound differentially. The current from an accumulator is passed through the lamp and a resistance in series with it, the lamp and resistance being shunted by means of the galvanometer coils. The resistance is made so as to equal

that of the lamp at any predetermined temperature, thus fixing the zero value of the pyrometer. The range of movement of the galvanometer needle for a given temperature interval can be regulated by means of a second resistance, and the two resistances and the lamp are made up in one fitting and are interchangeable

Fig. 11.—The Cambridge optical pyrometer.

with any other lamp adjusted for the same zero temperature and range.

An optical pyrometer, which possesses the advantage that the user can check its accuracy at any time and correct the calibration if necessary, is shown in fig. 11. The instrument may be regarded as a photometer in which a beam of selected monochromatic light

from the hot body is compared with a beam of similar light from an electric lamp.

As the accuracy depends upon the constancy of the light from the lamp, a regulating resistance and ammeter are provided to control the current. Light from the hot body under observation enters one aperture in the front of the pyrometer, and light from the electric lamp enters another. These beams of light then pass through a system of lenses and prisms, are polarised in different planes, and rendered monochromatic. Finally the two beams of light pass through a nicol prism into an eyepiece. The observer sees an illuminated circular field divided into two semi-circles.

One semi-circle is filled with an image of the hot body and the other is uniformly illuminated by the electric lamp. By rotating the eyepiece which carries the nicol prism, the two semi-circles are brought to an equal degree of illumination. The temperature is then read off on the large scale. Since both semi-circles are of

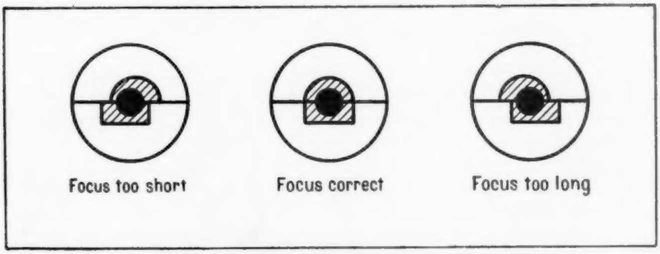


Fig. 12.—The field of the radiation pyrometer.

the same colour, readings can be made with great accuracy. As stated above, the instrument can be recalibrated at any time; this is done against a standard amyl-acetate lamp, thus ascertaining the reading of the ammeter when the electric lamp is giving the correct illumination. This test need only be made at long periods. The instrument is made in several ranges up to 4,000 deg. C.

The disappearing filament and the optical pyrometers use only the luminous rays from the hot body. The Fery radiation pyrometer employs all the radiation received from the hot body and not only the luminous rays. The radiation from the hot body is received on the concave mirror of a reflecting telescope, and brought to a focus on a small thermo-couple. The E.M.F. produced by the heating of one end of this couple is measured on an indicating or recording galvanometer. It is necessary accurately to focus the instrument on the hot body, and to do this an ingenious device is used.

The thermo-couple is fixed just behind a hole in a small mirror,

so that when the observer looks through the eyepiece he sees an image of the hot body in the mirror. Actually, this small mirror consists of two semi-circular wedge-shaped mirrors fixed together. If the instrument is correctly focussed, the appearance of the field is as shown in the centre diagram in fig. 12. The outer circle represents the mirror, the shaded portion the reflected image of the hot body, and the black centre is the sensitive element of the pyrometer. Care must be taken to see that the image of the hot body covers the sensitive element, otherwise correct reading will not be obtained. If the focus is not correct, the image will appear split in two parts, the fields when the focus is too short or too long being as shown in the left- and right-hand diagrams respectively.

The focus can be adjusted by means of a knurled head at the side of the telescope. Within wide limits this instrument is independent of the size of the aperture or the hot body sighted, and the distance of the telescope from it. The diameter of the hot body or aperture should be 1in. for a distance of 2ft. between it and the telescope.

This pyrometer is now used chiefly as a recording instrument. In such cases it is often necessary to fit a glass window to the telescope in order to exclude dust from the mirror. The instrument must then, however, be calibrated with the window in position.

Optical and radiation pyrometers are calibrated under "black body" conditions, and therefore will not give true readings unless used under the same conditions. A "black body" may be defined as a body which will absorb all radiations falling upon it, and will neither reflect nor transmit any. The radiation from such a "black body" is a function of its temperature alone. The ordinary commercial furnace practically fulfils "black body" conditions.

THE

INSTITUTION OF PRODUCTION ENGINEERS.

A GENERAL Meeting of the Institution was held in the Council Room of the Society of Motor Manufacturers and Traders, 83, Pall Mall, S.W., at 7.30 p.m., on Friday, February 20th.

The Minutes of the previous meeting were read and approved, after which Mr. H. A. Dean, of Messrs. Alfred Herbert, Ltd., Coventry, read a paper on "Grinding Practice," which was illustrated by lantern slides.

This was followed by an animated discussion in which several members took part.

GRINDING PRACTICE.

By Mr. H. A. DEAN, of Messrs. Alfred Herbert, Ltd., Coventry.

Those who have followed manufacturing methods for the past twenty years will have noted the ever widening scope of grinding. Confined at first almost entirely to the cutlery trades, and to the comparatively few parts which required precision, its machining value was not thoroughly understood, nor its application to bulk production appreciated.

This, of course, was very largely due to the fact that in the early days of grinding artificial abrasives were unknown, and quarried stone and emery so limited the choice that to obtain a really suitable abrading agent for every operation was impossible. The wide range of carefully graded wheels now available, and the data obtainable on speeds, feeds, etc., have changed practically all grinding operations from speculation to certainty.

In addition to this, the value of grinding as an agent for the removal of stock has become better realised, and as the need for closer limits has grown, machines have been evolved to perform an increasing range of operations.

Maximum speed in mass production, and accurate working to size limits, is most easily done with suitable grinding equipment, so that grinding has become an essential factor in the making of standardised duplicate parts. In the large field of mechanical industry it is being daily demonstrated that greater speed, closer accuracy and material reductions in operating costs invariably follow the introduction of up-to-date grinding methods into every possible phase of manufacturing.

To go fully into the manufacture of abrasives, grinding wheels, and the many factors affecting selection would require a paper to itself, so this subject will be touched very briefly.

Grinding wheels, as distinct from natural grit stones, are manufactured from two types of abrasives, an aluminous abrasive with Bauxite as a base, and a silicon carbide abrasive with silica sand and coke as a base.

The abrasive is bonded together by various processes, though at least 80 per cent. of manufactured wheels are vitrified. The chief reason for this is that the amount of metal removed per cubic inch of wheel wear with a vitrified wheel is very high, due to its porosity

and the great strength of the bond. In addition, vitrified wheels are not affected by water, acids, or varying degrees of temperature.

The aluminous abrasive grains are tougher than the silicon carbide grains; they do not break apart easily, and they withstand a greater stress, so are generally used on materials of high tensile strength, a dividing line between the use of the two abrasives being approximately 50,000 lb. per square inch.

A grinding wheel is sometimes compared to a milling cutter, but having an infinitely greater number of teeth or cutting points. To give an idea of the number of cutting grains which come into operation on a normal size of wheel, it is estimated that about 40,000,000 cutting grains act every minute on a wheel of 46 grain, 18in. diameter, 2in. wide, running at 5,000 surface feet per minute, and with a wheel 24in. diameter, 4in. wide, over 1,000,000,000 grains operate each minute.

A wheel, when it has worn down an inch or two from its original diameter, usually appears to cut better. The explanation is that the smaller diameter has reduced the arc of contact, with the result that the grains leave the bond more quickly as they are subjected to greater strain. If the surface speed is maintained each grain has to do more work in a given time, and therefore wears down more quickly.

The importance of correct wheel selection cannot be emphasised too strongly, the difference of one or two grades in bondhardness sometimes doubling the output.

Precision grinding has made great progress during the past few years, and the precision grinding machine has become one of the most important factors in the manufacture of present day machinery.

Production grinding should also be classified as precision grinding, for to secure the largest production of good ground work there must be considered the exact limits required for size and finish, and modern production grinding is always performed within exact limitation to some given rule or standard.

There are many classes of precision grinding, the most common being the grinding of cylindrical parts.

In studying cylindrical grinding, it is well to remember the close connection between the lathe and the grinding machine. The turner need spend little time in accurately finishing a part which has afterwards to be ground, as the grinding machine will correct any errors and imperfections in much less time than the lathe. Some firms now combine the turning and grinding departments into one for cylindrical work, and this policy proportions the time occupied by turning and grinding so that the minimum cost of production is obtained.

Three well-known types of plain cylindrical grinding machines may be mentioned. The Norton Company build a large range of

these machines, one of which is illustrated in fig. 1. Their chief features being a massive wheel spindle, ample speed changes, table and work speeds being independent, and the very convenient arrangement of all operating levers in the front of the machine.

A rapid power traverse to the wheel slide which operates in either direction is especially valuable for crankshaft grinding and similar work.

A heavy plain grinder is built by the Churchill Machine Tool Co. for the rapid production of medium length work. A feature of this machine is the table oscillating motion which assists in preserving the wheel face when form grinding.

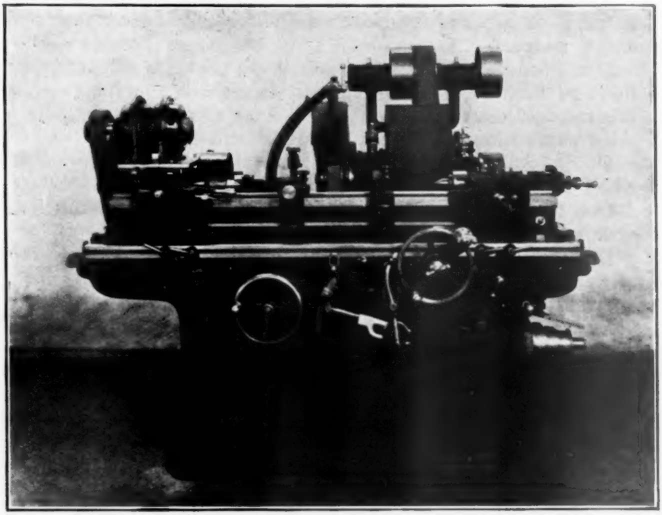


Fig. 1.—The Norton type A cylindrical grinding machine.

Machines built by the Landis Tool Company involve a different principle to the above, as these machines operate by traversing the wheel along the work which rotates in a fixed position.

There has been much discussion as to the relative merits of the travelling work table and the travelling wheel head. One point is obvious, which is that the various operating features are in a more convenient position with a travelling work table. With a travelling wheel at least a four-point bearing for the machine is necessary, whereas the three-point bearing eliminates any chance of strain or distortion. Actually, so far as the grinding operation is concerned, it makes no difference which way the machine is

built, the whole advantage lying in the ease with which the control mechanism and speed changes can be applied. The dividing line seems to be when the work is so heavy that more power would be required to move the work than to move the wheel head. In this connection it is interesting to note that the Landis Company are now making machines with travelling work tables.

Cylindrical Grinding.

Operators of grinding machines would be well advised to bear in mind these maxims:—

Don't commence to grind until you know the speed is right.

Don't start work with a new wheel without tapping it lightly to see if it is sound, and after mounting run it without cut for a few minutes.

Don't force wheels on to the spindle; a penknife will scrape out the lead bush to make wheels a sliding fit on the spindle; and don't forget that all wheels should have thin rubber washers or thick paper blotters between the wheel and the flanges.

Don't forget to change the belt on to the faster pulley as the wheel wears down.

Don't move head or foot stock before thoroughly cleaning the slide on which they move.

Don't forget that it is economy to use the right grain and grade of wheel for the work and that the time taken in changing wheels is quickly made up.

Economy in wheel wear is ensured by the use of the automatic feed, as a regular advancement of the wheel allows it to act under its normal effective conditions. Hand feeding as a general rule does not save time, unless the operator is highly skilled and exercises great care. The strength of the abrasive grain and the strength of the bonding material are effective only up to the limit of their ability to remain in place and withstand the shock upon them when grinding. If forced into the work the abrasive grains become loosened before they have actually served the proper length of time as a cutting medium, and the correctness of the wheel face is lost. Each wheel, relative to its speed of revolution and the speed of revolution of the work it is grinding, is good for a given amount of feed, and if the automatic method of feeding is used, the exact amount can be fed into the work with each stroke of the traverse.

It is universally true that where the automatic feed is adhered to production is at its highest point and quality always the best. Operators sometimes make the excuse when discarding the automatic wheel feed mechanism that it is always getting out of order. It would be well to remind such operators that the adage "Cleanliness is next to Godliness," is as true with regard to mechanical appliances as it is to more human affairs. If the

mechanism is kept clean and oiled regularly, he will be repaid by an increase in his bonus and a decrease in manual labour.

A very light cut with the diamond will true up a wheel which has been correctly used, but if it is necessary to remove 0·020in. from the diameter of the wheel, due to its rough usage, the loss in abrasive will be proved when you realise that 0·020in. removed from the diameter of a 20in. × 2in. wheel is approximately $2\frac{1}{2}$ cubic inches of wheel.

For roughing work the diamond should be passed quickly across the face of the wheel so as to break up the surface, and for finishing, light traversing cuts should be taken so as gradually to wear the abrasive grains down to a uniform height. On no account should a diamond be used without a good flow of lubricant, and the nozzle of the lubricating pipe should be so arranged that the lubricant arrives on the wheel at the exact point where the diamond is engaging the wheel.

The term lubricant in this connection means the cooling element, consisting usually of soda water or a grinding compound. It has several functions in addition to its most important one of carrying away the heat generated by the wheel during its cutting action. It carries away the dust as soon as it is made, it keeps the temperature of the work uniform, and also reduces the friction of the cutting particles of the wheel. A medium used with great success as a lubricant is Economy grinding compound, one part of which is mixed with 40 parts of water.

In grinding aluminium, trouble is usually experienced with scratches on the surface of the work, the main cause being that the aluminium chips float in the cooling lubricant and return through the pipe. A useful tip is to place a filter over the pump entrance in the tank to prevent the return of these chips, and to use as a lubricant a mixture of lard oil and paraffin in the proportions of one to ten.

Production in cylindrical grinding is greatly assisted by the correct use of steady rests. On large plain grinding machines the Universal steady rest is fitted with hard wood blocks, and the usual practice is to make these blocks interchangeable by sawing them from the solid wood at fixed angles (40 deg. one end and 80 deg. the other end). The rest should be so adjusted that the centre of the upper horizontal block bears on the work at its centre line. For smaller machines and where there are large quantities of parts to be exactly alike, hard steel steady rest shoes are recommended because they maintain their size.

The shoe should be exactly the same diameter as the finished ground work and should be allowed to come in contact with the work immediately upon starting the grinding operation. Adjustments to the steadies are made as the work proceeds, and a skilled operator can tell if he is maintaining the parallelism of

the work by the density of the sparks. Efficient steady rests ensure increased production, greater accuracy, finer finish, and greater ease in doing work.

Chatter is usually caused by the work not being properly supported with steady rests, or by the use of incorrect work speeds. Sometimes the driving dog sets up vibration, owing to the fact that there is torsion in the dog when a heavy cut is taken. When chatter marks are in spiral form of fine pitch, the cause is generally vibration of the wheel spindle. Driving belts of uneven thickness may cause chatter of the work, and sometimes the use of larger centre holes giving more support will remove the trouble, provided that the taper on the centre exactly corresponds to the taper in the centre hole. A glazed wheel causes chatter, and this can be overcome by paying particular attention to the relation of the wheel and work speeds.

Assuming that the machine is in perfect running condition and that the wheel is properly dressed and balanced, if chatter marks develop it is a sure indication that the work is not efficiently supported.

High production of duplicate parts is materially assisted by the use of wide wheels and a straight in cut, whereby the work is form ground by feeding the wheel direct on to work without longitudinal traverse. The Norton Special Purpose Grinder is a rigid machine for this class of work, and carries a wheel 7·5in. wide. An improvement has recently been developed for this machine in the form of a wheel spindle reciprocating attachment. An oscillating motion of 0·125in. is given thirty times per minute to the wheel spindle in the direction of its axis by means of a worm which turns a worm wheel having an eccentric on its shaft. This eccentric is in rotation whenever the spindle turns, but the pivoted yoke that transmits the oscillating motion to the wheel spindle can be thrown out of contact with the eccentric by a lever. The uniform reciprocating motion of the wheel gives a better finish and wheels stand up longer without truing. Automobile transmission shafts, 1in. diameter by 6in. long, are ground to half-thousandth limits at the rate of 70 shafts per hour removing about 0·025in. of stock. A 24 CM Alundum wheel will run for an hour before re-truing is necessary. Some typical production times on Norton machine are given in the table on the following page.

Centreless Grinding.

A comparatively new development in cylindrical grinding is the centreless grinder, the principal elements being a grinding wheel, a feed wheel, and a work rest. The main advantage of this method of grinding is that a continuous passage of parts across the wheel is ensured, and the time lost in dogging and centring the work is eliminated.

The work rotates at the same surface speed as the feed wheel, as this wheel is made of an abrasive bonded with shellac or rubber, and has a sufficiently rough surface to prevent slipping. The grinding wheel in its cutting action keeps the work firmly against the feed wheel and the work rest. Traverse speed is controlled by the feed wheel being set at a slight angle, so that the

MACHINE.	WORK.
6in. by 32in.	Spindle 17in. long, ground 7/16in. dia. for length of 12in. Stock removed 0·025in. Limits 0·001in. Time 3 minutes each.
	Shaft 20in. long, ground all over, four different diameters. Stock removed 0·020in. Limits 0·0005in. Time 8 minutes each.
	Camshaft 32in. long, ¾in. dia. Stock removed 0·015in. Limits 0·0005in. Time 9 minutes each.
10in. by 50in.	Shaft 23in. long, ground on 8 different diameters to 0·001 limits. Stock removed 0·025in. Time 15 minutes each.
	Rear axle shaft 28in. long. Ground on both ends 8in. up to 1-1/16in. dia. and limits of 0·001in. Time 4 minutes each.
	Shaft 50in. long, 2in. dia. Stock removed 0·030in. Limits 0·00025in. Time 18 minutes each.
18in. by 120in.	Cast Iron Drum 41in. long, 6in. dia. Stock removed 0·050in. Limits 0·0005in. Time 40 minutes each.
	Shaft 7ft. long, 8in. on largest diameter. Seven different diameters ground removing 0·040in. of stock to limits of 0·001in. Time 1 hour 35 minutes.
	Flour mill roll 53in. long, 9in. dia. on roll 30in. long, two bearings 3in. dia. Stock removed from large dia. ¼in. Time 60 minutes.

centres of the feed and grinding wheels do not fall in the same plane. Traverse speed changes are effected by a slight alteration of this angle and a change of speed of the feed wheel.

A smaller grinding allowance can be made for centreless grinding as compared to grinding between centres due to the fact that centre type machines work from a radius, while centreless machines

work to the nearest full diameter. The work being rigidly supported at the exact point of grinding, heavier cuts may be taken, and more uniformly accurate work is assured.

The gain in production on centreless machines over centre type machines varies according to the type of work from 200 per cent. to 1,000 per cent. A fair average increase is 400 per cent.

Cam Grinding.

The advent of the forged camshaft having a number of cams integral with the shaft necessitated the design of a cam grinding attachment.

Where a variety of work is done, it is usual to drive the attachment through the headstock of the machine, and any length of

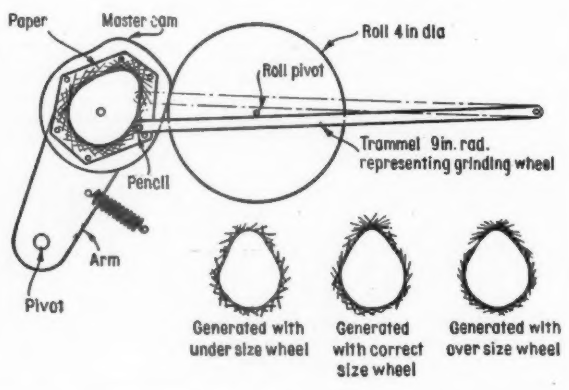


Fig. 2.—The principle of the cam grinder.

camshaft up to the capacity of the machine can be handled satisfactorily. A rear view of the headstock end of the attachment shows the driving arm, the master cams on the master cam spindle, the roll which locates the proper cam to be ground, the shaft on which the roll slides, and the encased spring which holds the master cam snugly against the roll. The arrangement is shown diagrammatically in fig. 2.

As the master cams revolve and bear against the roll the attachment oscillates about the centres. The wheel is fed into the work until the desired shapes are produced, and a handle is located in the front of the headstock to lift the work away from the wheel when moving the roll from one position to another.

Efficient steady rests are essential for the accurate grinding of integral camshafts, and as strong a flow of lubricant as possible, to keep the temperature uniform.

Loose cam attachments are made on exactly the same principle, and the work is ground on centres supported by the overhanging arm.

The work speed for roughing integral camshafts should be about 60 r.p.m. and the finishing speed 15 r.p.m.

For finishing cams the grinding wheel must be of a similar size to the roll which was used in forming the master cam, and should be discarded for this work when it has been reduced in diameter by 2in., for the following reason:—

The work oscillates before the grinding wheel and also revolves about a fixed centre, the centre hole being concentric with the heel of the cam. As the camshaft revolves the heel comes in contact with the wheel at a point resting on a straight line drawn from the centre of the wheel to the centre of the camshaft, the side comes in contact below this line, while the toe of the cam touches at the lowest point. These points must remain in contact with the wheel until they reach a point as high above the centre as the point at which they first came in contact is below the centre. With a smaller diameter of wheel it is obvious that each point on the contour of the cam comes in contact with the wheel at a different time and remains in contact for a lesser period.

Coarse, hard wheels (about 36P A1 in Norton grading) are best for cam roughing, and finer, softer wheels (24 comb. J) for finishing. A soft wheel for finishing is very necessary, due to the fact that the surface speed of the work when the toe of the cam is in contact with the wheel is extremely slow, and chatter marks would otherwise occur.

Internal Grinding.

Internal grinding is a subject of great importance to the machine tool maker and general manufacturer.

As with cylindrical grinding, two types of machines are used for plain internal work, one with a traversing wheel spindle, and the other with a travelling work head. For production work the former is much more efficient, as this is a single-purpose machine.

The internal grinding machine is not a stock removing tool, and it is better and quicker to let the boring machine bring the hole to within about 0·010in. of the finished size, this amount varying slightly according to the diameter and length of the hole and whether the work is hardened or not. Of course, a sixteenth of an inch can be ground out of a hole if necessary, but if output is required, the grinding allowance should be just sufficient to allow the hole to clean up accurately to the required size.

Always use wheels without lead bushes for internal grinding,

as lead bushes in small wheels travelling at high speed are apt to cause vibration, and remember that it is better to wear wheels down quickly and get greater output than to save on wheels and slow down production.

Very frequently the grinding operation itself takes so little time that unless efficient chucking methods are adopted, the cost is prohibitive. For this reason quick-acting self-centring chucks

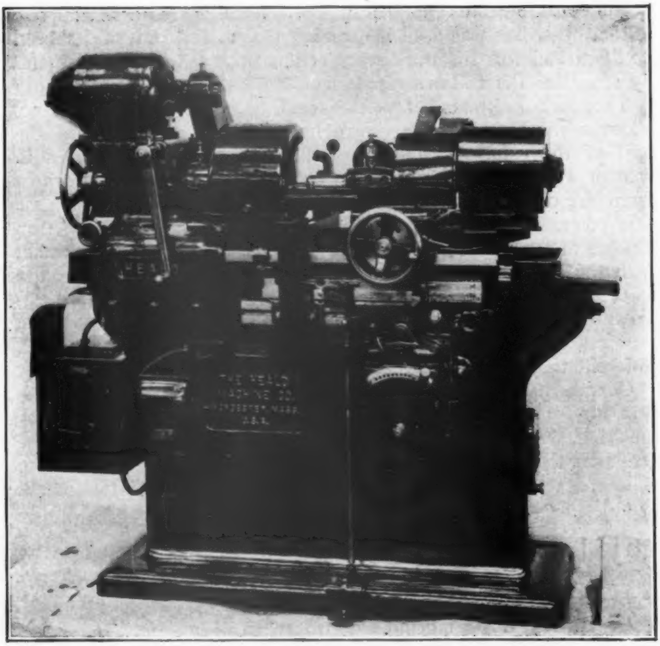


Fig. 3.—The Heald internal grinder with hydraulic table drive.

are used, and the Heald Co. fit to all their plain internal grinders a collet chuck with detachable jaws. This is operated by a lever with an adjustable compensating device which prevents the work from being distorted by pressure.

Another useful attachment with Heald machines is a holding fixture for bushes and work with thin walls. This consists of a barrel-shaped holder mounted on the spindle of the machine. The collar at the rear of the bush is threaded to fit the inside of the holder, making it adjustable for any length of bush. On the

front end is a removable cap threaded to the end to clamp the bush endwise while grinding the hole. The cap and the collar are each fitted with interchangeable plates, having holes slightly larger than the holes to be ground. To facilitate centring, a plug of triangular section is used, which can be withdrawn as soon as the bush is firmly clamped.

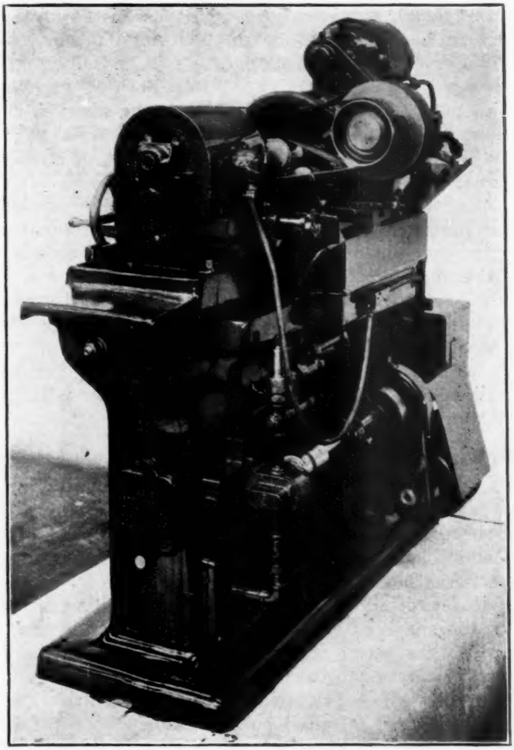


Fig. 4.—Rear view of the Heald No. 72 internal grinder.

A machine of considerable interest has been recently produced by the Heald Co. This machine is illustrated in fig. 3, whilst a rear view is shown in fig. 4. It is practically automatic, gearless, and very dependable, due to the simplicity of its mechanism. The table is driven by a simple hydraulic arrangement, operated

by oil, enabling the operator to obtain instantly any speed from zero up to maximum. Movement of a lever gives a quick withdrawal of the wheel head, the table moving at maximum speed to the end of its stroke, where it stops and a guard automatically covers the wheel. The table returns with equal high speed until it reaches the work when it automatically resumes the proper grinding speed.

The work head, mounted on a solid base, is so arranged that the water supply is started or stopped simultaneously with the work spindle. The wheel-truing device is an important labour-saving feature, as it can be swung into position and the wheel trued without stopping the work and leaves the wheel in a position to continue the grinding to the finished size. As the table is driven by oil pressure, there are no gears, racks, or other mechanism to cause shocks or vibration.

This is a very valuable machine for the high production of duplicate parts, as waste time is practically eliminated. The wheel grinds on the far side of the hole, and to reduce gauging to a minimum an electrical indicator is fitted, having a diamond point in contact with the near side of the hole while the work is being ground. By using this indicator, the work can be ground without stopping the chuck until a small lamp lights up, when the wheel is withdrawn for truing. After resuming, grinding proceeds until a second lamp lights up, when the hole is true to size. The indicator is sensitive to 0·00025in.

Cylinder Grinding.

The present success of the automobile is mainly due to the accurate grinding methods employed in its manufacture, and the cylinder being the fundamental component of the automobile engine, the efficiency of the whole mechanism lies to a great extent in the proper grinding of this part.

All cylinder grinding machines have one thing in common. Owing to the shape of the cylinder block the work must remain stationary, so the wheel spindle is designed to give the wheel a circular or planetary movement.

The grinding spindle is carried in double eccentrics, one inside the other, which are mounted on the headstock of the machine. The two eccentrics may be rotated relatively to each other, to increase or decrease the eccentricity of the wheel spindle, and thus give the wheel a circular path of varying diameter.

No fixed rule can be given for determining the proper combination of eccentric and table traverse, since the speed and feed depend on the kind of wheel being used, the amount of metal to be removed, the hardness of the iron, and more also on the operator.

Some operators prefer a slow speed for the eccentric and a

table traverse equal to three-quarters of the width of the wheel for roughing, and speed up the eccentric for finishing.

A more common method is to use the fastest speed of the eccentric and the slow speed of the table, taking 0·003in. to 0·004in. at each inward pass, and 0·002in. at each outward pass. Twice up and down the hole with no cut on at all will give, in nearly all cases, a round straight hole and good commercial finish.

The question of wet or dry grinding for cylinders has been thoroughly tested, and the general experience has been all in favour of dry grinding. To keep a uniform temperature it is recommended that water be run in the jacket, or over the outside of the cylinder.

A good jig is essential to obtain satisfactory production and accuracy; one designed to handle all sizes of blocks in such a manner that when strapped in place the holes will be centred with the grinding circle.

The jig shown is made up of two heavy bars bolted to the face of the angle plate. To set up a block, move the top bar so that the zero mark will register the diameter of the hole to be ground on the scale at the side. Clamp the bar in position and slide the locating brackets along the bar until they are at the same distance apart as the two end holes of the block. Clamp the cylinder on the locating rods, withdraw the rods, slide the brackets out of the way, and a slight movement of the table will give perfect alignment.

A machine with a large capacity is built by the Churchill Machine Tool Company. The grinding head is a heavy, self-contained unit which has four speeds of reciprocation, four independent speeds of planetary motion, and can be arranged with any number of grinding wheel speeds to suit the diameter of the wheel in operation. This ensures grinding conditions remaining constant when grinding a number of bores in an irregularly shaped piece.

Automobile Work.—Times.

In dealing with production times it is impossible to give a definite formula whereby given results can be predicted. A formula which is determined for certain conditions is not correct over a range of work, due to the many variables that enter into production as related to grinding. The chief factor which destroys any formula is the personal element, which varies with each individual operator.

It is interesting, however, to consider some times which are regularly accomplished in certain works on important grinding operations. The Ford Motor Co. is a good example, as the grinding methods employed here have been decided on after

careful study, and the saving of a few minutes is of the utmost importance.

Every manufacturing step in this firm is executed by a workman who devotes his entire time to one operation, or one series of operations, and as a result of constant repetition, the man becomes a production operator of great skill.

Another important factor is the manner in which the various manufacturing units are laid out. Each department is equipped with all the necessary plant for the production of a specific part of the car.

A layout of this kind involves a large initial cost, but the operating economies effected by cutting out inter-departmental transport costs more than compensate for this outlay. Automatic conveyors are used for transporting parts from one machine to another and from one department to the next. These conveyors are usually of the endless, chainbelt type, on which receivers are spaced at intervals for accommodating parts.

The fixed wheel, or form grinding principle, is employed extensively at the Ford plant, and for this method rigid machines and wheels which cut freely while maintaining a true face are necessary.

Ford crankshafts are rough turned before grinding. They are made of drop forged, heat-treated steel, and the four crankpins are ground at the rate of 50 per hour, removing 0·030in. of stock, and with a work speed of 15ft. per minute.

The camshafts are drop forged steel, and are roughed out on the lathe, case hardened, and finished by grinding. The front and rear bearings on these shafts are finished at the rate of 70 per hour. The work is run at a surface speed of 20ft. per minute, and no traverse is used, the wheel being fed directly into the work. The centre bearings are finished at the rate of 90 per hour.

There are 8 cams on the shaft, four inlet and four exhaust, and these are generated with a cam grinding attachment at the rate of 25 shafts per hour, removing 0·030in. of stock from each cam. The wheels used on the cam grinders are salvaged from the crankshaft grinding shop, as the diameter at which they are discarded for crankshafts is just right for the cam contours.

The hole in heat-treated steel ring gears ($5\frac{1}{4}$in. dia., $\frac{3}{8}$in. long) is ground at the rate of 120 per hour, removing 0·015in. of stock.

When the transmission is assembled the outside diameters of the three drums are ground on a Norton plain grinder equipped with special roller bearing centres. The ground surface is 7in. dia., 4in. wide, and 70 transmissions per hour are roughed to 0·005in. over size. A similar time is taken on the finishing operation, and about 100 transmissions are finished with one truing of the wheel.

Heat-treated steel-drive shaft sleeves are finished at the rate of

130 per hour. They are $1\frac{1}{4}$in. dia., $3\frac{1}{16}$in. long and 0·030in. of stock is removed. The work speed is 15 surface feet per minute, and several arbors for mounting the work are provided, so that work can be loaded while the grinding is in progress.

There are two grinding operations on the drive shafts for Ford motor trucks. A surface $1\frac{1}{4}$in. dia. by 6in. long is finished at the rate of 50 per hour, and another surface $1\frac{1}{8}$in. dia. by $3\frac{11}{16}$in. long is finished at 80 per hour.

The tapered portion of the axle shaft that fits the rear wheel is form ground, the grinding time being 100 shafts per hour, removing 0·040in. of stock.

Centreless grinders are used at the Ford plant for finishing the large number of bearing rollers ($\frac{1}{2}$in. dia., $3\frac{5}{8}$in. long). The machines are equipped with automatic hoppers, which contain a feed arm actuated by a motor that keeps the feed trough on the grinding machine filled constantly. Four roughing cuts and one finishing cut are necessary to remove 0·020in. of stock to bring the bearings to size. On the roughing cuts the pieces pass through the machines at the rate of 80 per minute, while the finishing time is 120 pieces per minute.

For the above particulars of grinding operations in the Ford works I am indebted to Mr. Fred B. Jacobs, the editor of "Abrasive Industry," and his book on "Productive Grinding."

Gear Grinding.

Gear grinding is now an important factor in modern production. The demand for smooth-running gears in automobiles has been the incentive to develop machines which will grind gears quickly and accurately.

Ground gear teeth are more durable and efficient. The same factors which cause noise and wear in gearing are those which cause loss of efficiency. Hardened gears develop slight distortions due to the heat-treating processes, and in addition extreme accuracy in the preliminary gear cutting is not necessary if the gears are ground.

The requirements of machines for gear grinding are :—

That they grind tooth faces smooth ; that they grind the faces to true involute form, and that they be provided with a good indexing device so that teeth will be properly spaced.

One type of gear grinder shapes the tooth form by the direct cutting section of the wheel, which is operated in the same way as an ordinary cutter. The shape of the form is reproduced on the grinding wheel by a special wheel truing device, and the wheel traverses through the space.

Another popular type of gear grinding machine is the generating type where the flat side of the wheel engages the work in a similar manner to a rack tooth. The work holding device of the machine

is designed so that the gear to be ground rolls along the theoretical rack profile from the position A to C in fig. 5. At the point B, between A and C, the face of one tooth comes into contact with the wheel, which generates upon it a true involute curve. Having rolled the gear in one direction, it is reversed and rolled back to the original position A. The indexing mechanism then advances the gear one tooth, and one face of the next tooth is ground in the same manner. The operation continues until all of the teeth have been ground on one side. The gear must be reversed on the arbor to grind the other side of the teeth.

The Fellows Gear Shaper Co. have recently developed an

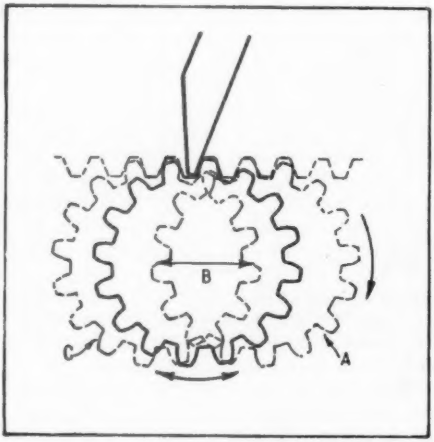


Fig. 5.—The principle of the gear grinder.

automatic gear tooth grinder for the production of gears in large quantities. This machine is shown in fig. 6.

A special feature is the small size of grinding wheel which is used. This obviates the necessity for a long arbor and work spindle, making the machine very neat and compact. A small wheel can also be trued much more quickly, and the automatic truing device ensures only a light cut being taken. Having determined the necessary amount of truing, the machine automatically duplicates this, and the mechanism can be so timed that the wheel is dressed after the gear has made one or more complete revolutions.

After setting up, all that is required of the operator is to locate

the gear to a gauge provided, clamp it on the work spindle and pull a lever.

The machine takes care of the rolling action of the gear against the flat side of the grinding wheel, indexing for each tooth, truing

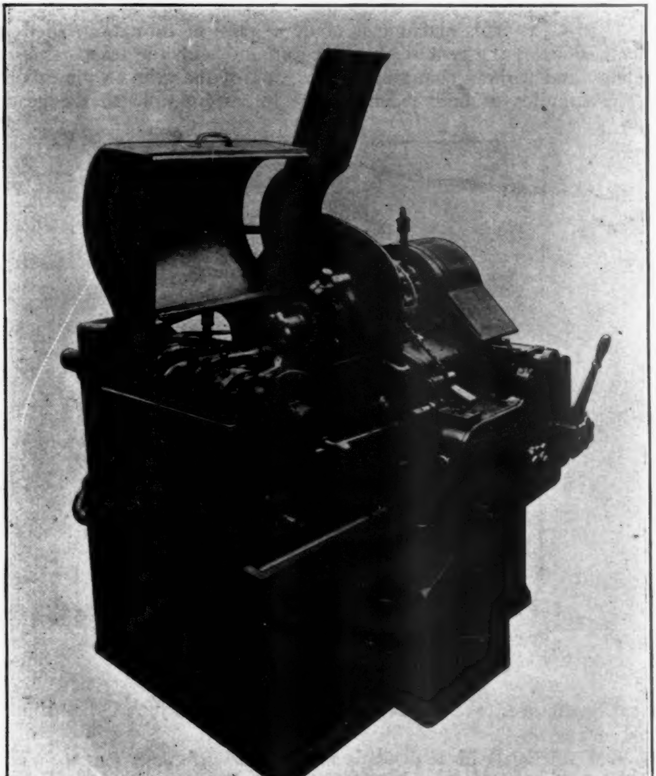


Fig. 6.—The Fellows automatic gear tooth grinder.

the flat side of the wheel, and stopping the machine when the gear has been completed.

The gear, after being fixed to the machine spindle by a suitable mandrel, is compelled to roll through a path which is determined

by contact between a master involute tooth A and an adjustable abutment B, shown in fig. 7. The former is secured to the rolling head, and the abutment to the machine bed, the interaction of the two members resembling that of a gear tooth rolling on a rack. The grinding wheel is immediately beneath the gear. A very satisfactory wheel to use on this machine is Norton AL.36 CJ. This machine is made in tandem formation, so that both sides of the gear teeth can be ground with the least possible delay and without changing the location of the gear on the arbor. The spindles of both machines are interchangeable so the gears

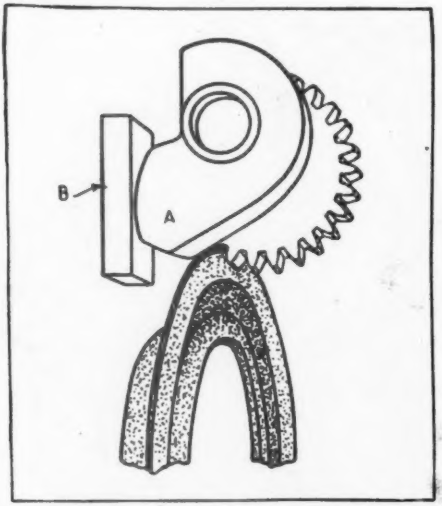


Fig. 7.—The master involute gear grinder.

can be changed over by removing the mandrel without disturbing the gear.

The rolling head as a whole is removable (fig. 8), and may be interchanged with other heads by simply removing the caps from the trunnions. This is necessary when different sizes of gears have to be dealt with.

Surface Grinding.

Surface grinding in its early days was practically confined to tool room work, and was used for finishing parts which had been milled or planed approximately to size. To-day the grinding of plane surfaces is a manufacturing proposition, and the surface

grinding machine has displaced the milling machine on many operations. Recent developments in this field have been due mainly to the successful application of the segmental grinding wheel. It is a significant fact that in many manufacturing concerns ring wheels on existing machines are being replaced by segmental wheels.

For general tool room work a small surface grinder with a reciprocating work table is still indispensable.

The rotary type of machine using a disc wheel is also very useful for certain classes of small work, such as clutch discs,

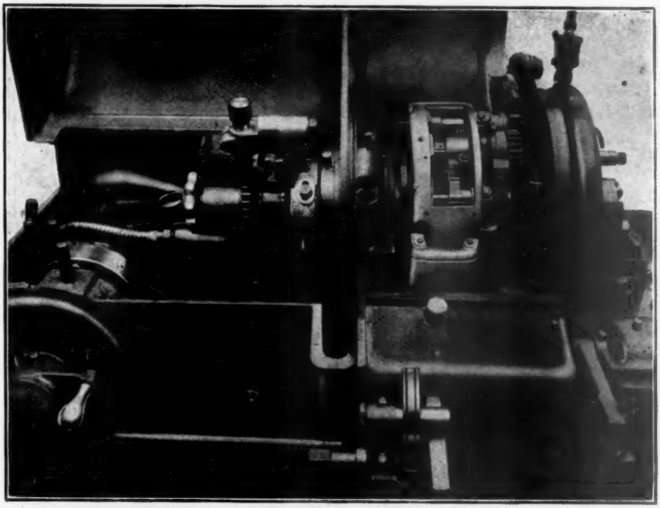


Fig. 8.—The wheel, arbor and rolling head of the Fellows gear grinder.

piston rings and washers. With the disc wheel and rotary table a very fine concentric finish is obtained.

The following is an example of work ground on a Heald No. 25 machine. A cast iron clutch ring 12in. dia. outside and $9\frac{1}{4}$in. hole has 0·050in. removed from each side of the rough casting in 1min. 45sec.; wheel wear about $\frac{3}{8}$in. in 10 hours. On this machine the slide is hydraulically driven by oil, enabling the operator to get any speed desired. By turning an auxiliary speed valve it is possible to get a slow forward travel and a quick return, which allows the removal of a large amount of stock with very slight wheel wear.

Vertical spindle ring and cup wheel surface grinders are also

of two types, reciprocating and rotary, and each type is very efficient in dealing with its own class of work, the reciprocating type being used mainly for grinding long rectangular surfaces, and the rotary machine for discs, washers, and similar pieces.

The Norton openside surface grinder (fig. 9) is a slightly different type to either of the above, as the periphery of the

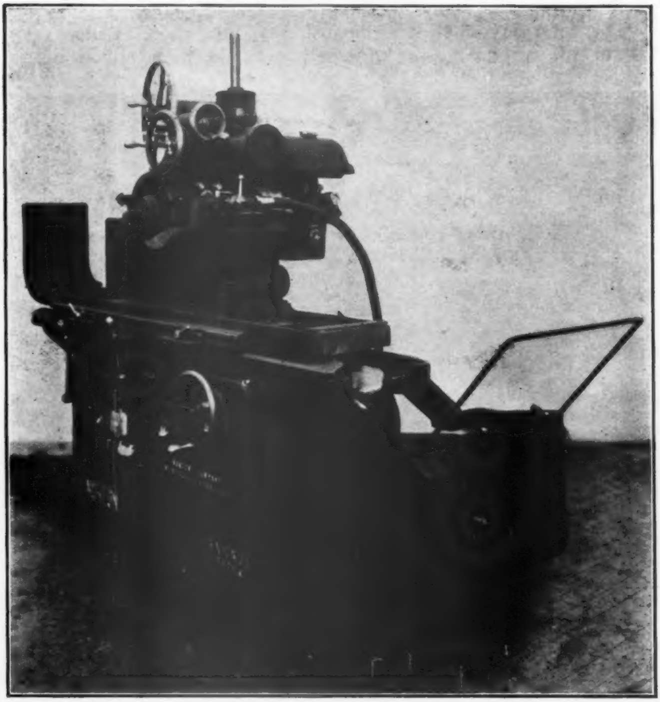


Fig. 9.—The Norton openside surface grinder.

grinding wheel is used on this machine. As the maximum diameter of wheel used on this machine is 14in. the arc of contact is reduced to a minimum. The standard wheel used is 6in. wide, so that a large area is covered with one traverse of the wheel.

The grinding wheel mounting is hung from a cross slide which moves at right angles to the travel of the table. The cross slide is carried on a vertical slide which may be raised or lowered

on a column by a small motor. Heavy work can be accommodated on the table, as the maximum space between a new wheel and the table surface is 17in.

The inexperienced sometimes wonder why only one speed for wheel and one for table traverse is provided on surface grinding machines. Obviously one speed only is necessary. The design of the wheel sleeve limits the size of the wheel both maximum and minimum to such an extent that a change of speed would mean no economy in wheel wear. On a Norton openside machine the wheel is used from 14in. dia. to 10in. dia.

On the work table, no matter whether the piece is short or long, the rate with which it travels underneath the wheel is always constant, which is very different to cylindrical grinding where

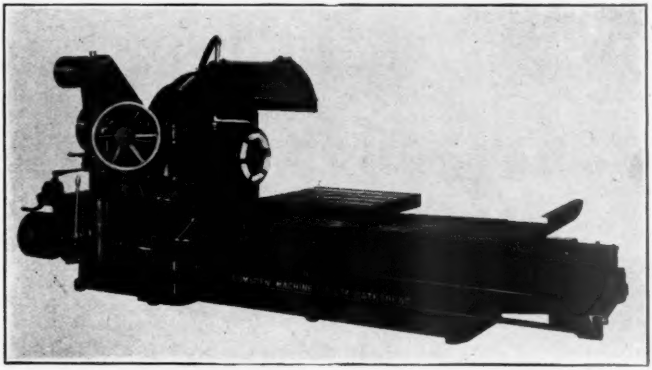


Fig. 10.—A planetary head surface grinder.

work speed changes are necessary, due to the variety of diameters the machine will accommodate.

A complete range of machines for surface grinding parts from the rough instead of planing and milling is manufactured by the Lumsden Machine Co. The segmental wheel enables the abrasive to be supported close to its cutting surface, and also allows plenty of chip clearance, which is a most important factor in removing metal. Twenty cubic inches of cast iron have been removed per minute with a 30in. segmental wheel.

The planetary head surface grinder shown in fig. 10 is of great interest, as with this construction work of unusual dimensions can be dealt with efficiently on a machine of comparatively small size, and correspondingly small cost. The segmental wheel spindle is mounted in a planetary carrier, so that the wheel will

grind a surface of double its own diameter. The saddle has a quick movement by power on the bed, and the work table is also rotated by power.

Two examples of production show the capabilities of this machine:

In one case a cast-iron pipe cross having four flanges is ground in a total time of 20 minutes, removing 0·093in. to 0·125in. from each face. Three of the faces are 17½in. dia. and the fourth 14½in. dia.

A cast-iron switch gear case has from 0·062in. to 0·093in. ground from the face in four minutes (size 31in. by 17in. by 1⅜in. rim).

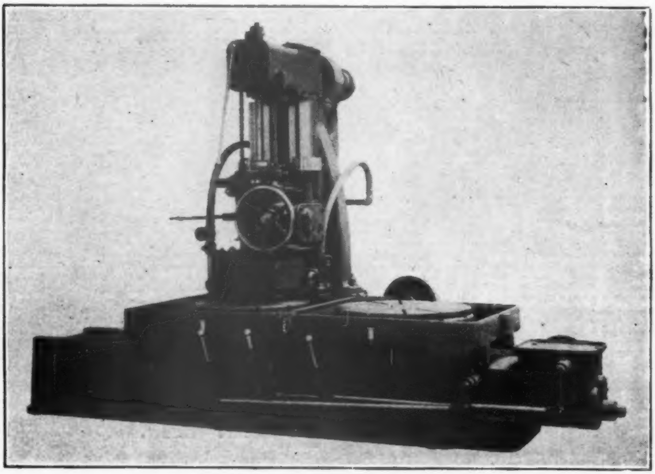


Fig. 11.—The Lumsden twin rotary table surface grinder.

The horizontal spindle surface grinder is being used successfully in the production of flat surfaces on locomotive parts, textile, and electrical machinery.

A mild steel buffer cylinder (12in. by 9in.) can be cleaned up on the face in 3 minutes.

A cast-iron tank cistern can be cleaned up on two faces in 3 minutes, and 0·125in. of metal can be removed in 7 minutes (Size of faces 32in. by 10in. and 14in. by 8in.)

In the grinding of small parts the time required to load the table is as much as the time occupied in grinding the work. The Lumsden twin rotary table surface grinder overcomes this diffi-

culty, and obviously has double the output of a single table machine. This machine has a spiral bevel spindle drive, and the two circular work tables are mounted on a travelling carriage moved by power.

Two instances of production times are given.

A chuck load of 56 cast-iron change gears was ground in a total time of 8 minutes, removing 0·062in. from each face.

A chuck load of cast-iron change gear quadrants (comprising

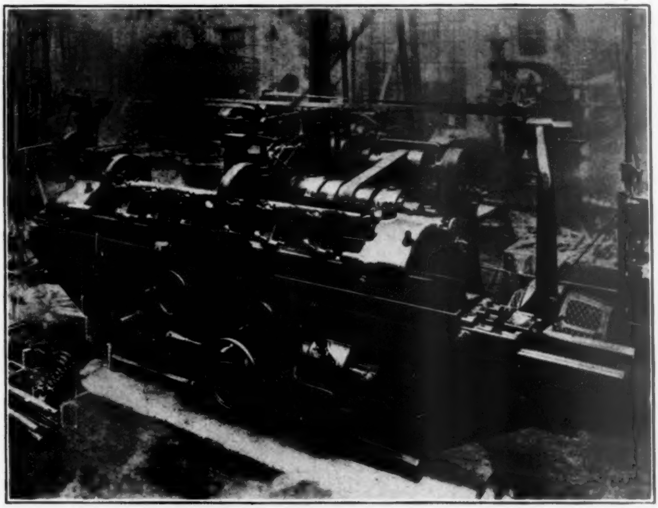


Fig. 12.—A piston rod grinding machine.

15 small and 12 large) had 0·093in. removed from each side in a total time of 30 minutes.

Railroad Work.

The railway industry has derived much benefit from the precision grinding machine, both in the manufacture and repair of rolling stock and in the manufacture of rails, switches, and cross-overs. The motion gear, a vitally important part of a locomotive, is ground on all working surfaces, with a resultant decrease in manufacturing cost and increase in mechanical efficiency.

The introduction of high temperature superheated steam, the use of higher boiler pressures, and the ever-increasing power of loco-

motives have combined to magnify piston and valve rod packing difficulties. The metallic packing now used cannot hold steam and stand up for any length of time unless rods are smooth, accurate cylinders.

Special cylindrical grinding machines are used for piston rod grinding with pistons in position. The machine shown in fig. 12 is built by the Churchill Machine Tool Co., and will accommodate

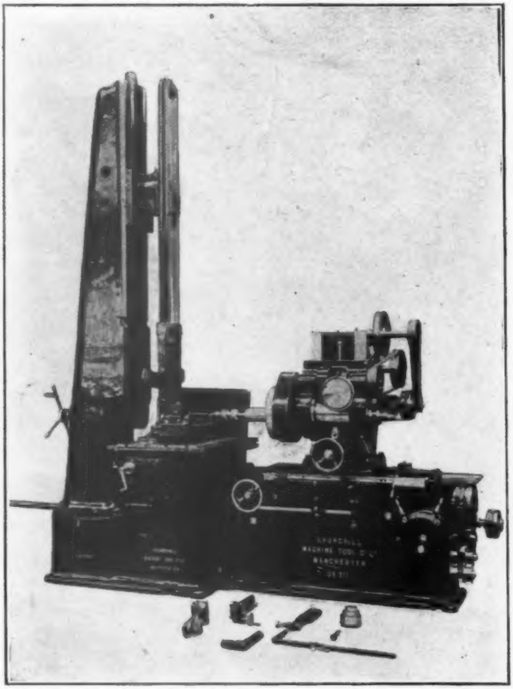


Fig. 13.—The Churchill radius link grinding machine.

a piston 23in. in diameter. The grinding time to remove 0·025in. from the diameter of a single-ended piston rod is 14 minutes. To remove 0·031in. the time is approximately 25 minutes, depending on the condition of the rod. Another machine by the same firm with a gap to admit work 30in. dia. by 4ft. long is very useful, as the gap can be placed anywhere on the table to accommodate individual requirements by means of a sliding gap piece.

An Alundum wheel 24 Comb. L is used for piston and valve rod grinding.

Axle journals give the best service when ground cylindrically. The smoother and more accurate any bearing surface is, the less the friction will be, with a resulting decrease in depreciation rate. A tender axle with two bearings 5½in. dia. by 11in. long and two bearings 6½in. dia. by 7¾in. long is finish ground, removing 0·062in. from the rough-turned diameter in 40 minutes on a Norton 18in. by 96in. plain grinder.

The Churchill combined cylinder, surface, and radius link grinding machine, shown in fig. 13, is specially designed for

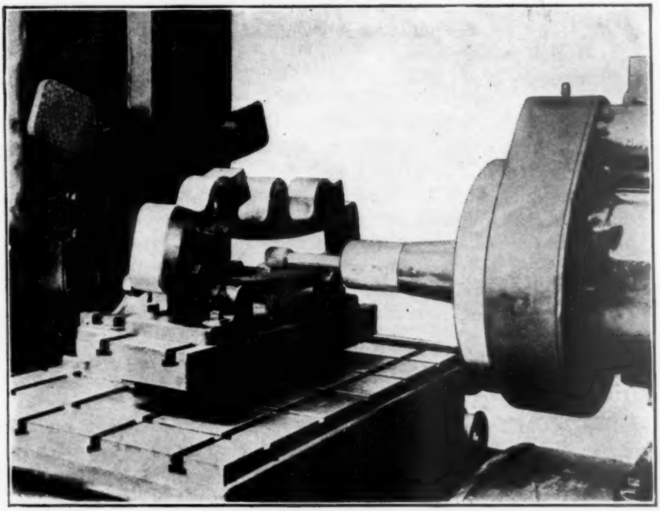


Fig. 14.—Grinding a radius link on the Churchill No. 2 machine.

locomotive work. With the aid of the pendulum link grinding motion it will grind any normal locomotive expansion link, both in the slot and the holes. The upright column is mounted on a special base, so that the pendulum link grinding mechanism can be swung clear of the table for cylindrical surface grinding.

The link shown in fig. 14 is ground in 40 minutes on the radius portion, and the two holes for the eccentric pins are ground in 5 minutes each. The Churchill No. 3 internal cylinder grinding machine illustrates a comparatively new feature in locomotive practice, as the piston valve liner bore is ground at the same

setting as the cylinder bore, thus obtaining a higher degree of accuracy than with the boring machine.

The time required to grind the locomotive cylinder 20½in. dia. by 30in. long, removing 0·031in. from the bore, is from 2 to 2¼ hours for each bore, and for the valve holes 9in. dia. on a similar cylinder 1½ hours for each bore.

The Norton openside surface grinding machine has been very successfully used on various plane surface grinding operations where a perfectly flat surface is required. Very few jobs require to be strapped down; they are merely placed flat on the table of the machine, a strip which extends the full width of the table being clamped at each end of the job. An interesting example of this is the grinding of a steam chest cover. This is supported at the four corners on four adjustable screw packings, and is set parallel to the machine table by the aid of a height gauge in 1 minute. It is ground with a 36I. Crystolon wheel in a gross time of 22 minutes.

Slide bars 2ft. 6in. long by 2¾in. by 1½in. in cross section are ground ten at a time in one table load. The bars have about 0·030in. to be removed from each side, and they are ground to 0·001in. limits with an Alundum 14-16J. wheel in a total time of 3 hours 25 minutes, or an average of 20½ minutes for each bar. This time includes setting up and handling. On this machine it is possible to clean up a surface 9in. wide by 5ft. long, removing 0·006in. in 4½ minutes.

Connecting rods, expansion links, etc., are ground in a similar manner.

Grinding Rolls.

The manufacture of high-grade paper is dependent on the perfect finish of the rolls used, and the grinding of large calender rolls is almost a subject in itself. Some of these roll grinding machines weigh as much as 50 tons, and carry wheels up to 10in. in width.

In a large paper mill in Canada a roll stock consists of ten rolls. The bottom roll is 30in. dia., and weighs 44,000 lb. The next roll is 20in. dia., and weighs 18,000 lb. There are seven intermediate rolls 14in. dia. weighing 9,000 lb. each, and the top roll is again 20in. dia. All the rolls are 196in. long. A stack of rolls similar to the above has a capacity of 240 tons of paper a day.

These large rolls are ground on a machine made by the Farrell Foundry & Machine Co., with a capacity of 36in. by 17ft. This machine carries two grinding wheel heads, driven by individual motors, and the two wheels grind simultaneously on each side of the roll. The two motors are mounted on a superstructure

over the carriage to eliminate long overhead drums, and the wheel heads travel along the length of the roll on V-shaped ways. On this type of machine the grinding wheels, instead of being mounted rigidly, are suspended from A frames on the wheel carriage, and the two wheel carriages are connected by a cross bar so that they move together. The swing rest mechanism is supported on knife edges of tool steel, which in turn are supported on knife edges on the connecting cross bar. This design allows a free lateral movement to the wheel heads, and ensures a parallel roll as the wheels pass along the roll in a perfectly straight path.

The necks of the roll are placed on two brackets with bearing metal shoes, and the roll is driven by a flexible coupling. Roughing cuts of approximately 0·002in. are taken, and finishing cuts of not more than 0·0005in. The traverse feed is 1in. for each revolution of the roll, and work speed is 25ft. per minute. Grinding time to remove 0·006in. from a bottom roll is approximately 90 hours.

As long calender rolls sag with their own weight, the bottom roll must be crowned so that the top presents a parallel surface for the next roll to rest on. To provide for this, on one side of the machine bed an arched plate is located. A toe piece on the wheel carriage travels over the master plate as the carriage moves along its ways and through the medium of levers, the wheel heads are moved away from the roll as its longitudinal centre is approached, and towards the roll after the centre is passed. The amount of crowning is determined solely by experiment, and is a trick of the trade acquired by constant practice.

Grinding in some form has long been used for making rolls serviceable after they have become worn in the steel rolling mill. The up-to-date method is to combine shaping and polishing by using a cylindrical grinding machine. This method saves considerable time, and greatly prolongs the life of the rolls. It is estimated that a roll finished by grinding has 50 per cent. longer life than one dressed by turning and lapped. As grinding forms practically a perfect cylinder, the rolls remain in service much longer, and produce results equally as good as the lapped rolls.

A comparison of the times required to dress rolls in the lathe and on the grinding machine establishes the fact that the lathe time for an average roll (say 30in. by 90in.) is four times that required to finish the roll in the grinding machine.

In grinding chilled rolls over 12in. diameter, it is sometimes advisable to use a wheel smaller than the maximum size the machine will carry. If the surface speed is correct, a harder wheel than usual can be used efficiently due to the reduction of the arc of contact. With a wheel at full size and a consequent large arc of contact intermittent wheel crumbling often takes place.

Semi-precision Grinding.

Semi-precision grinding comprises operations which are partially machine grinding, but which also depend on hand manipulation to some degree. Typical instances are the slotting of granite and marble, the surfacing and moulding of marble on planer type machines, the cutting of marble and slate slabs on coping machines, the rough grinding of pearl button blanks, the grinding of car wheels, the surfacing of manganese steel rails, and the smoothing of tramway rails.

An interesting operation in the marble industry, known as coping, is the cutting of slabs of marble into sections having correct widths. Coping wheels are made around a steel centre, and are tapered slightly from the periphery towards the centre. The wheels are made from silicon carbide abrasive bonded with shellac.

Portable electrically driven grinding machines are very useful when attached to lathes, planing or milling machines for grinding railroad frogs, switches and cross-overs, and other articles made of manganese steel, which is very difficult to machine.

Portable electrically driven rail and track grinding machines are also extensively used to remove corrugations from street tram rails, or to remove the excess metal left on tram rails from the welding operation.

Grinding plays an important part in the cut glass industry, cut glass being of a different quality to moulded glass. It is purer, more dense, and has a higher index of refraction, which causes it to reflect more light. The grinding wheels used in the manufacture of cut glass are mainly of the aluminous abrasive type, and they are specially prepared. The speed at which these wheels should run is much slower than the normal vitrified wheel speed, this being necessary to avoid splitting the edges of the glass.

The manufacture of optical lenses involves the use of abrasives in nearly every operation, and grinding wheels are employed in paint making to grind the pigments and oils together.

The rapid production of flat cutlery is aided by the automatic grinding machines used. A Hemming knife grinding machine will grind one gross of table knife blades in an hour. Elastic bonded wheels are used on these machines owing to the danger of heating and drawing the temper from the knives, and the range between hardness limits of wheels that can be used efficiently is very small.

Miscellaneous Work.

A very important development in the last year or two has been the substitution of the sandstone by artificial abrasive wheels. Owing to the large size of wheel required silicate bonded wheels were used at first, but now large vitrified wheels can be made for

all classes of work. In the textile industry, wheels 40in. dia. by 14in. wide are used to clean up the various cast-iron machine parts. For this work the Carborundum Company manufacture wheels 40in. dia. by 7in. wide, and cement and bolt two wheels together to form one wheel of the required dimensions.

The Norton Company have perfected their manufacturing methods so that solid wheels 40in. dia. by 14in. wide are made of even texture throughout by the vitrified process, and can be duplicated with confidence.

Artificial wheels have a much longer life, and because of this slow wear they maintain their surface or form better. They are quicker cutting, and wheels can be exactly duplicated year in and year out. The difficulty with sandstones has always been that even from the same quarry, stones vary in hardness and therefore grinding conditions in a shop where they are employed cannot be standardised very well on a production basis. Perhaps the chief feature of this development is that in contrast to the sandstone the use of artificial wheels does not affect the lungs of the workman.

With very few exceptions there is no article that could not be ground as well on manufactured wheels as on sandstones, and in most cases more cheaply. The chief trouble to overcome in this change is the natural prejudice of the old sandstone grinders, but this will die out in time as there are very few recruits on this work.

Where manufactured wheels have been thoroughly tested without prejudice the operators would not now go back to sandstones under any conditions, due to the great improvement in the sanitary condition of the workshop and the increase in production maintained.

Both the smallest and the largest parts known in machining practice can be economically ground. Grinding has long passed the stage when it was used only for precision work on hardened parts. High speed cutting tools are used for many operations to-day where grinding would increase the speed and decrease the cost.

Old practices, like old habits, are hard to change, but those who are investigating the comparative merits of the grinding wheel and the steel cutting tool are having their eyes opened to both the precision and production possibilities of modern grinding.

THE DISCUSSION.

MR. E. W. HANCOCK: I should like to thank the author for his comprehensive paper. In connection with cam grinding, I have had experience of the difficulty of getting a fine cut all round the cam. On the face of the cam we have a line contact, and as the wheel follows round we increase the arc of contact, and the flanks of the cam continue to touch for some considerable period afterwards. In connection with the Churchill cam-grinding attachment, or any of the attachments which have the eight cams, I should like to ask the author's opinion as to whether he thinks the eight master-cams are as good as two master-cams with a dividing head for giving the 90 degrees division. It seems to me that in a shop where one deals with small numbers and different forms of cams the two master-cams are preferable, inasmuch as they enable a quick change to be made from one set of formers to the other and a reasonably quick introduction of a new form of cam. Also when using only the two cams you are likely to get greater accuracy. In an automobile cam shop it is consistency rather than actual form which gives the best result. In connection with chatter marks on cams, by putting a brake on the spindle the trouble that one gets on the nose of a cam has been reduced, but it is not removed altogether. Another point in cam grinding: does the author think that a weight to keep the masters against the rollers is better than a spring? With the spring, as the lifting force varies, so does the pressure. There is another point. I feel that the advance of grinding has called for a larger number of fixtures to be used, and, as far as I can see, the sizes of the work-heads are inadequate. A normal sized fixture is very difficult to carry on an inadequately proportioned head. It is invariably necessary to put a steady on the bed to support the overhanging fixture. In connection with cylinder grinding and gear grinding, it is very necessary to bring the work to a fair degree of accuracy before grinding. The nearer one can get with the gear, the better it is both from the point of view of consistent results and of keeping a uniform hardness, without any soft spots on the gear. Another point I would like to ask the author is in connection with the introduction of the broad wheel grinding. What methods are adopted in balancing the wheels? Are they put only in static balance, or in dynamic balance? Is there any attempt at automatic adjustment of steady-rests on grinding machines? In view of the possibilities of error it would seem worth while to get down to a really efficient automatic steady-rest. I should like to know the author's opinion of the fixed quill versus the moving quill on large internal grinders. I believe there is a Swiss machine which has a stationary quill, and the wheel only is given the planetary motion. That gives a more rigid support to the wheel. I forget the name of the machine.

Mr. Dean: I do not know of any automatic method of adjusting steady-rests, and I do not see that it is a practicable proposition, though it is ideal certainly. With regard to the balancing of the wheels for the large width, they are actually put in static balance only. I quite agree that on gear grinding it is necessary to bring the work to a much more accurate finish than is required for cylindrical grinding. I also agree that on the smaller types of machines difficulty arises from the weakness and smallness of the heads, but that difficulty is overcome on a larger machine. As far as the use of the weight for cam grinding is concerned, I have had no experience; I have had no trouble with the spring. Offhand I should say eight masters were to be preferred, but if I went over it as carefully as the speaker has done I might come to the same conclusion as he. But I should say at the moment that the results from the eight masters would be quite accurate. I am not sure of the Swiss machine to which the speaker referred.

Mr. H. E. Weatherley: The machine mentioned is the Kellenberger.

Mr. Hancock: I have a few notes on the Fellowes gear grinder. It is an interesting machine, but no one has had practical experience of its capabilities over here as yet, so far as I know. We have a machine under demonstration at Coventry, and we manage to get gears off in four minutes—gears of about 24 teeth. It gives 30 strokes a minute, and these gears are ground in two revolutions. The actual time taken to grind a gear about 4in. in diameter with 20 teeth is 4½ minutes, and we do not find any trouble at all with the wearing of the wheel. I have not really had the experience to know how long the wheel will last before it is worn out.

Mr. Weatherley: Referring to cam grinding, in the best method I have yet found the weight of the cams is directed against a fixed roller. The weight on the head is right against the roller itself; that is equivalent to a weight, is it not?

Mr. Johnson: One speaker mentioned a 0·004in. cut in and out on the grinding wheel. In my experience I should say that is not obtained in manufacture owing to the imperfections in the cylinder block and to heating in the boring operations, especially with cast-iron blocks. The pressure to take a 0·004in. cut for the ordinary sized wheel and spindle would not give a round bore, as the quill itself would undoubtedly give to the imperfections produced in the boring operations.

Mr. Dean: It is a practical proposition to take a cut of this depth. There is no trouble at all from distortion in the cylinder or spring in the spindle.

A Member: In the Ford plant, I believe, there are two or more men operating each machine. The comparison with English methods, therefore, is unfair.

Mr. Dean: I think I have explained that in a part of the paper that I did not read. I was not holding these Ford figures up as a standard for English practice. The operators are, of course, on the one-job year in, year out. The workman devotes his entire time to one operation.

Mr. Hugo: That is a practice not valid for England, and therefore these times are very misleading.

The Chairman: With regard to any times quoted from the Ford factory, no man in the Ford factory works any harder than the man who " does his bit " in an English factory. I had the privilege of spending a few weeks in the Ford plant in Detroit, and the very fact that the men did nothing else—and had not done anything else for years—than the jobs they were on, does help considerably in the matter of times. I have been able to modify quite a number of jobs after seeing how they do them. I also think it would be possible to improve on some of their methods in an English factory. But one must take into account that on any job whatever the Ford Co. are doing per day more than the average British factory, excluding perhaps one or two, can carry out in a month. Before we could get a job really set out on the same lines as they work we should have done perhaps a year's output. There is one other factor that helps considerably. In the Ford factory they do not mind wearing their machines out. I have seen one or two boring operations completed at a speed which would kill the machine in six months. They say that even so they do not mind, because the machine will have earned its money. I think, if I remember rightly, some two or three years ago they were cutting at about 95ft. a minute on steel tubing with a feed of 0·025in. per revolution to a limit of 0·002in. In any English factory there would be no difficulty in getting a man to keep the same times if only there was enough for him to do to get him used to his job. But I think you can take it that any times you see quoted from a Ford factory can be substantiated, and I do not think that anything they do in the Ford factory is incapable of being reproduced in this country provided a sufficient number of parts are to be manufactured.

Mr. J. Bass: It seems to me strange that seldom or never do we see it stated as to what is really the secret of efficiency in grinding. It is never laid down definitely how to get at it. One finds in catalogues and textbooks on grinding that the wheel surface speed is generally from 4,000 to 6,000ft. per minute, but seldom does one get the working speed, which is of the utmost importance. It seems to me that the ratio of surface speed to the wheel speed should be definitely laid down. Has the author any definite information on this point? The author has said that we should not expect internal grinding to be a stock-removing operation. I think it is because internal grinding has presented so many difficulties that it has more or less been side-tracked.

Mr. Dean: Apart from the difficulty of getting an adequate cutting pressure without spring, the trouble with internal grinding is that one cannot get the speed, *i.e.*, the recommended surface speed.

Mr. Bass: I think you can get the speed. Why have not the makers gone in for something like a bronze journal and a bronze bearing spindle? These would stand it quite all right, and you would get up to 25,000 or 35,000 revolutions a minute.

Mr. Dean: We are getting up to 25,000 revolutions with ball bearings.

Mr. Bass: One would not use a ball-bearing spindle.

Mr. Dean: With regard to the work speed that was mentioned, I have compiled a chart of my own for work speeds for various materials for external grinding and internal grinding. From 80 to 110 feet per minute is a good surface speed to start from on internal grinding of hardened steel. For cylindrical work 30 to 35 feet per minute, and for finishing 50 to 55 feet per minute are suitable. There was one point mentioned about the conversion of existing machines to the oil-driven type. I do not think that is practicable; I believe the expense would be too great. I am not quite sure whether it could be done at all, but I am almost sure that there is an English firm adopting that principle. I believe the Churchill Company have adopted the oil-power drive.

Mr. Hey (Member of Council): With reference to cam grinding, I might say that long before the war, in Nottingham, the system employed was by compressed air, and that has been working, to my knowledge, for some time. Several firms have been using the same method. With reference to the speed of the small internal wheels for internal grinding, turbine-driven wheels have been in use in this country for the past four or five years. In 1918 I patented a turbine myself for that very purpose. A good many of these have since been manufactured. Speaking of segmental wheels and one speed for surface grinders, I do not agree with one speed for those machines; my experience has shown that with various surfaces a change of speed is necessary. Some time ago I had experience of a 20in. segmental wheel with 10 segments. I removed half the segments and more than doubled the output; then I took out another segment and increased the output again. We decided then to put in smaller segments of a different shape, and we got better results still. Speaking of sandstone and wheel-grinding, I should like to know whether the author has had any experience in Sheffield with regard to better output with grinding wheels as against sandstone. Taking an ordinary pair of scissors on a sandstone, a man performs five operations in $7\frac{1}{2}$ seconds. I would like to see the grinding wheel where that job can be tackled mechanically and give greater production than is obtained by the old-fashioned methods. It took me six months to tackle this class of work; we have done it, but it was one of the stiffest jobs I have ever undertaken. When grinding shafts does the author suggest putting the keyway in first and grinding after? The question of the Heald oil-driven type of machine has been discussed a good deal. I do not know whether it is known that that type of machine was brought out in Germany. I had a machine in 1901 that was made in Germany for grinding 24in. cylinders, and it is on exactly the same lines as the Heald machine to-day. That machine was installed in Nottingham.

Mr. Dean: With regard to Sheffield I have had quite a lot of experience. Another operation in addition to the scissor grinding mentioned is the grinding of circular saws. The only way out of that difficulty is to evolve new machinery which will work under different conditions, and that seems to be the main trouble. The same thing applies to the substitution of natural segments by artificial segments. There again, on a machine like the Tasker-Snow

type, the speed is too slow. My experience with regard to shaft grinding is that it is always policy to cut the keyways after grinding. There is distortion sometimes, but it seems the best way out of it.

Mr. Weatherley : The segmental wheel and the cylindrical wheel is still a big subject of controversy. The segmental wheel for castings of anything of a soft nature where there is stock to be removed is a good proposition. But as soon as you have to deal with hard material it is wrong, because you cannot guarantee that each segment will be of equal hardness, and you get a series of chatter-marks.

Mr. Dean : The segmental wheel principle applies to particular classes of work. For anything solid or hard it is not a good proposition.

Mr. Locker : The grinding of thin tubes and sleeves is an interesting proposition. I heard recently of the sleeves for a sleeve-valve engine, 0·031in. thick in steel, having to be ground internally and externally.

Mr. Dean : The only way to do that would be to rough out or even to finish the diameter to a given size and slide it into a slightly tapered bush to grind the bore. The trouble there would be, I suppose, that you would get the sleeve sticking in the bush afterwards.

Mr. Hancock : On the engine I have in mind, the sleeve is not 0·031in. thick, it is just over 0·062. The success of the method traces right back to the very first operation. If you can produce a round bore in the first operation and the sleeves are accurate right through you are more likely to get good results. The way I have arranged it is to bore the sleeve first, taking great pains in the boring. It is then put on the mandril, for turning outside diameter. Next the bore is ground by inserting the sleeve into a fixture which has a contracting collar; a very slow taper and very accurately made. Some people just pour water on the outside of such fixtures in order to keep them cool. The method I have adopted is to rip up the outside and encase it with lagging keeping it water-tight. There are two small exhaust holes in the front, and water is introduced from the back so that there is an even temperature of water all round the sleeve. The main point about a sleeve is to keep the walls of uniform thickness.

A Member : A very important factor in grinding sleeves is a proper annealing process.

The Chairman : I would like to point out to Mr. Dean that there is one subject he has missed from rather a wide paper, and that is thread-grinding. We may look upon the grinding machine as being one for accurate work, but on threads, I think, we have still got quite a lot of work to do, and I shall be glad to know if there are any late developments on that type of machine, and whether they are proving a commercial success or not. When we consider the accurate work that can be produced on modern grinding machines we are almost coming to a point now in which rather different methods of measuring the work after grinding must be employed. There was also a point which I appreciated in the author's remarks

with regard to the use of small wheels—that it was preferable to use small internal wheels without lead bushes. That is a fact. There is another point on the internal wheel, and that is, not to be afraid of wearing the wheel out. That is a point sometimes overlooked by the management in some factories, that they make a lot more fuss about wearing out a wheel that may have cost a couple of shillings than about wasting a man's time. That is a thing that Americans do take particular note of—they do not mind machine wear, providing it is producing at maximum efficiency, but they prevent labour waste. The labour that we employ on production is the most expensive item as a general average.

Mr. Dean: There were two very obvious omissions; one was ball grinding, and the other was thread grinding. I omitted thread grinding because I have had no experience of it.

Mr. Weatherley: I have been away from grinding for four years now, but just towards the end of my last experience we were experimenting with thread grinding, and we got down to a suitable wheel. If I remember rightly it was a question of the wheels being too light. The essential point in thread grinding is to get wheels as soft as we can and as fine as necessary.

Mr. Hancock: I was surprised that in connection with the broad wheel mentioned there was no dynamic balancing. In a wheel or disc about 8in. long serious trouble might be set up on this account. I had a little experience in dynamic balancing, and it is really surprising on a normal flywheel, about 4in. wide, the couple that can be set up. I think that the operation of dynamic balancing, which should not be difficult, ought to be undertaken by the people who produce the wide wheel.

Mr. Weatherley: I do not think this is possible.

Mr. Hancock: An error in dynamic balance can all be resolved and put into one position, and that position can be found, and the proper correction made. You need not necessarily endeavour to wipe out a couple although I do not see any difficulty in doing that.

Mr. Locker: I would like to propose a vote of thanks to Mr. Dean for his very interesting and informative paper, and also to the Society of Motor Manufacturers and Traders for their kindness in allowing us the use of their room for this meeting.

Mr. Weatherley seconded, and the vote of thanks was carried by acclamation.

Mr. Dean: This is the first time I have ever given a paper on a technical subject, and I congratulate myself that it has elicited some very useful opinions from members of the Institution, which will be very helpful to me later.

VISIT TO THE COWLEY WORKS OF MORRIS MOTORS, LTD.

By the courtesy of Messrs. Morris Motors, Ltd., an official visit of a party of members of the Institution of Production Engineers was made on March 12th to the company's works at Cowley.

The party consisted of the President, Mr. W. L. Fisher, Messrs. A. Butler, H. E. Honer, R. H. Hutchinson, G. Hey, W. F. Dormer, A. T. Davey (Members of Council), and about fifty members and friends. After lunch at the Clarendon Hotel, Oxford, they proceeded to Cowley, where an exceedingly interesting afternoon was spent examining the methods by means of which the firm handle their present output of 1,000 cars per week.

This output is unique in British practice, and to deal with it the organisation has been developed on original lines, especially in the production of engines, where "continuous" rather than mass production is the outstanding feature of their work.

Engines are delivered complete to the Cowley works, fully tested from the works of Morris Engines, Ltd., at Coventry, and the same procedure is adopted with regard to the complete gear box unit. The bulk of the remaining parts are supplied by subcontractors all over the country.

In view of this, it would not be surprising if unforeseen difficulties and delays occurred in the assembling departments. Further, it needs very little imagination to picture the result of even a minor hitch in a continuous assembly line covering 30 or 40 operations. Members were, therefore, interested to enquire whether any troubles arose on this account. They were assured that, with the exception of one shut-down of four hours, there had been no delay or trouble in this direction since the system was first introduced.

In the foundry, members commented on the extent to which hand moulding methods are retained. All cores are made by hand, and although a battery of machines is employed for cylinder block moulds, machine methods are not adopted to anything like the extent which might be expected. It was explained in connection with this that the cylinder casting and crank case top-half was a most difficult piece of work, and that the expense of hand-ramming was fully justified by the very small proportion of scrap made.

A sand-slinger machine of the stationary type has, however, been installed, although it is not yet regularly employed. The machine is surrounded by a circular track, and the impeller head

Fig. 1.—I.P.E. Members photographed outside the Cowley Works.

is carried on a radial arm swinging about the central pillar so that a number of moulds may be rammed economically. This machine was fully described in *Engineering Production* for

August, 1924. One of the difficulties in the foundry is the lack of space, which will be appreciated when it is mentioned that, although initially laid out for the production of castings for 150

Fig. 2.—A view of the rear axle assembly line.

cars per week, 800 sets of castings are now being turned out in the same period.

On leaving the foundry the castings are transported by road to

the works of Morris Engines, Ltd., at Coventry, and the same lorries return loaded with finished engines. Each engine is placed on a trolley to facilitate handling as soon as it enters the Cowley works, and the engines are passed into a series of racks or runways, from which they are withdrawn and placed on the assembly line by means of a travelling hoist. They are then fitted with the electrical gear and all the accessories which can conveniently be assembled before the engine is mounted on the chassis.

Another assembly line, a portion of which is shown in the accompanying illustration, deals with rear axles; a simple arrangement consisting of a revolving star or turntable to enable a right-angle bend to be made in the track will be noted. The chief interest attaches to the chassis assembly line on which 32 chassis are in progress simultaneously. The time cycle of this line is 2½ minutes, so that a car occupies 80 minutes in passing from one end to the other.

It should be mentioned that the chassis is propelled along a wooden track by hand after the wheels and tyres are fitted, and for raising the chassis for coupling up the brakes, etc., compressed air jacks centrally situated in the track are utilised.

The other departments which the Institution party visited included the power house, the sheet metal shop, the bodybuilding department, the paint shop and varnishing shop, and the final fitting and finishing department. A somewhat surprising feature is the extent to which hand tools, such as hand drills, screwdrivers, etc., are employed. Very little use appears to be made of tools driven either electrically or by compressed air.

THE

INSTITUTION OF PRODUCTION ENGINEERS.

A General Meeting of the Institution was held at the Engineers' Club, Coventry Street, W.1, on Friday, March 20th, Mr. Butler, Vice-President, occupying the Chair.

The Minutes of the previous meeting were read and approved.

Mr. S. N. Brayshaw, of Messrs. Brayshaw Furnaces & Tools, Ltd., Manchester, then read a paper on "The Hardening of Carbon Tool Steel," which was followed by an interesting discussion.

THE HARDENING OF CARBON TOOL STEEL.

By Mr. S. N. BRAYSHAW, M.I.Mech.E., of Messrs. Brayshaw Furnaces and Tools, Ltd., Manchester.

This paper has been written to draw attention to the importance of the heat treatment of carbon tool steel prior to hardening. From one point of view the title might appropriately have been "The Annealing of Tool Steel." The author maintains that the best results obtainable from carbon tool steel depend not so much upon the final hardening process as upon the previous annealing or heat treatment.

Strangely Discordant Results.

Alloy steels are now made in great quantities for various purposes, and it is well known that if any advantage is to be obtained from their use they must undergo certain heatings and coolings which can usually be prescribed with confidence. Generally, there is in the heat treatment an allowable margin of variation within which the working may easily be maintained in a well-equipped shop, and there is no doubt about the results that will follow. In contrast to this there is in the hardening of carbon tool steel a marked degree of uncertainty, and the surprising fact stands out that this state of things is generally, if not universally, accepted as inevitable and beyond remedy.

The author has been studying hardening cracks for many years, and on one occasion, when he put forward a series of observed results to show that, after all, there was some hope in attacking the problem, a leading authority refused to examine the subject and summarily dismissed it by asserting that "anyone engaged with tool steel knew that with exactly the same treatment carried out with the greatest care, it was often possible to get strangely discordant results from the same bar." That statement was absolutely true, but instead of regarding such a condition of things as inevitable and unalterable the author could desire no clearer justification for his research. In opposition to such an attitude, he would say that there was a superabundance of unexplained occurrences, but there was nothing fundamentally inexplicable. There was much about the behaviour of steel that was unknown but nothing unknowable.

A Carbon Tool Steel.

The author has made thousands of carefully observed and recorded experiments, mainly upon a high-class tool steel of about the following analysis.

Carbon ...	... 1.13	Nickel ...	... *nil*
Manganese	... .34	Chromium	... .18
Silicon ...	... .14	Tungsten	8
Sulphur ...	... .035	Vanadium	... trace.
Phosphorus	... .017		

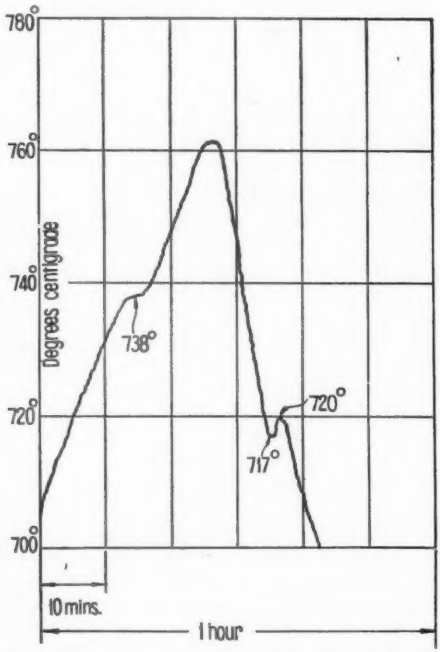
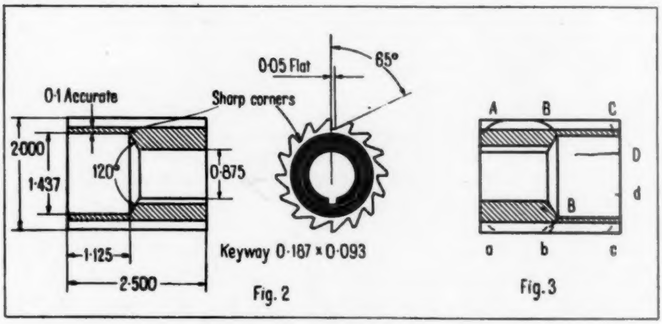


Fig. 1.—A heating and cooling curve for a high class tool steel.

A heating and cooling curve of this steel is given in fig. 1. The halt in heating Ac 1, 2, 3 occurred at 738° C., and on cooling the halt Ar 3, 2, 1 began at about 717° C., followed by an actual rise in temperature of two or three degrees.

Test Cutters.

The behaviour of the steel was investigated in order to find a treatment by which it could be hardened with reasonable certainty of producing, even in the most difficult cases, a thoroughly good cutting edge or wearing surface without risk of cracking or warping, and for this purpose a large number of test cutters were made as shown in fig. 2. These cutters were machined alike within fine limits, so that their response to various heat treatments and hardening processes might be affected as little as possible by chance conditions. They were designed to present extreme difficulty in the hardening, and it was evident that any method capable of dealing satisfactorily with such pieces, leaving them truly hard and sound, must be very good indeed.



Figs. 2 and 3.—Typical test cutters.

When the cutters had been hardened they were dried and soaked in oil, then they were sandblasted and examined for cracks, which could be detected by the appearance of the oil on the sandblasted surface. In order to provide some standard of comparison, one, two or three defectiveness marks were assigned for every crack or break according to its degree of badness. A cutter which broke round the recess into two pieces was given three marks for each of the 16 teeth, amounting to 48, and then there would be further marks for cracks at either end. Fig. 3 shows a cutter with typical cracks. A, B, C, and D are all bad cracks, for which 3 marks would be assigned in each case. *a*, *b*, *c*, *d* are slight cracks, for each of which one or two marks would be assigned. A cutter which had a minute crack on each of five teeth would have a defectiveness of five assigned to it, although there might not be a fault capable of detection by ordinary examination; whilst a cutter with no flaw beyond a single tooth badly cracked in one place would have a defectiveness of only three. Obviously,

comparisons by means of defectiveness figures must not be pushed too far; there was no exact standard for assigning the numbers and chance conditions might have a great influence upon the actual amount of breakage. A group of test cutters after hardening is shown in fig. 4, and some typical cutters are shown in fig. 5.

Heating in a Salt Bath.

It was evident at the outset that no progress could be made unless the treatment were brought under such control that any specified process could be carried out with great accuracy, and accordingly the salt bath furnace was adopted for heating in all cases.

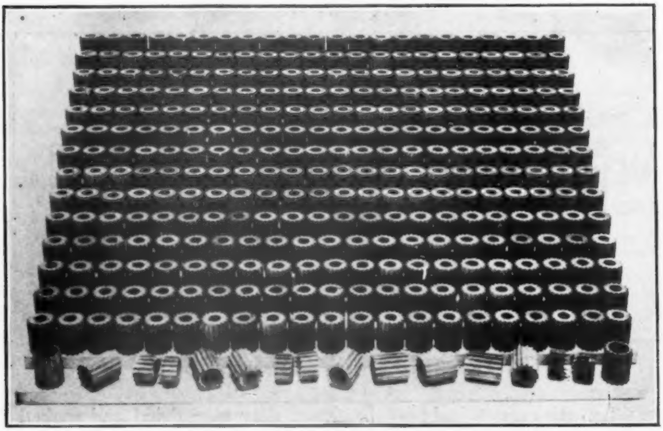


Fig. 4.—A group of test cutters.

There is a certainty about heating in a liquid not attainable by any other means. When using a salt bath the work and a pyrometer are both placed in a liquid to which a specified amount of stirring is given either by mechanical means or by an operator guided by a clock. It is obvious that in a short time the work and the pyrometer must reach the same temperature, and the pyrometer readings are true indications of the work itself. In a salt bath there are four factors which affect the heating, as follows :—

1. The composition of the liquid.
2. The temperature of the liquid.
3. The time of immersion in the liquid.
4. The stirring in the liquid.

All of these can be described with absolute precision, and they can be controlled in actual work to such an extent that any deviation from the lines laid down shall be so slight as to be negligible. Under these conditions, and with careful working, it can be positively stated that if similar results are not obtained from similar treatment, the difference has arisen in the steel, and not in the process, and thus it is possible to locate the source of the erratic behaviour with which every hardener is acquainted.

Two furnaces were used for this work, and they both contained pots 11 inches diameter inside and 16 inches deep. The pots

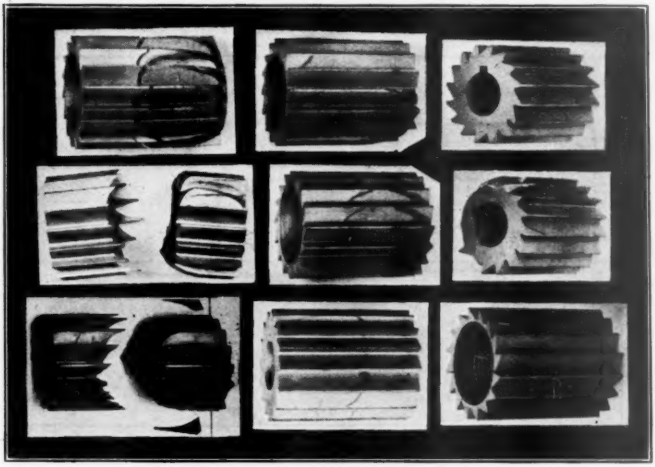


Fig. 5.—A selection of typical cutters.

were filled, within about 3 inches of the top, with pyromelt composed mainly of chlorides of barium, potassium and sodium. In each furnace the weight of the pot was about 1½ cwt., and of pyromelt about 1 cwt. thus the total weight of each pot and its contents was about 2½ cwt., which was sufficient to prevent rapid fluctuations of temperature. Each furnace was fitted with a counterbalanced tray to carry the work and at the same time to act as a stirrer. During the whole of the time that the cutters or blanks were in a furnace, whether for normalising, heat treatment, or hardening, the pyromelt was stirred every 2½ minutes by two quick double strokes of the tray from the bottom of the bath to the top right out of the liquid and back again.

Temperature Measurement.

Some of the heat treatments described later were carried out in two furnaces, the work being quickly transferred, after a certain time, from the first furnace to a second at a lower temperature. In these cases the regulation of the heat in the first furnace was the less important, and accordingly the first furnace temperatures of 750°, 800°, 850° and 900° C. and the normalising temperature of 825° C. were shown by a "Thread" recorder in conjunction with a "Titan" thermocouple, which is an iron-constantan couple made of wires $\frac{3}{16}$in. diameter. The cold junction was maintained at a temperature within a degree or two

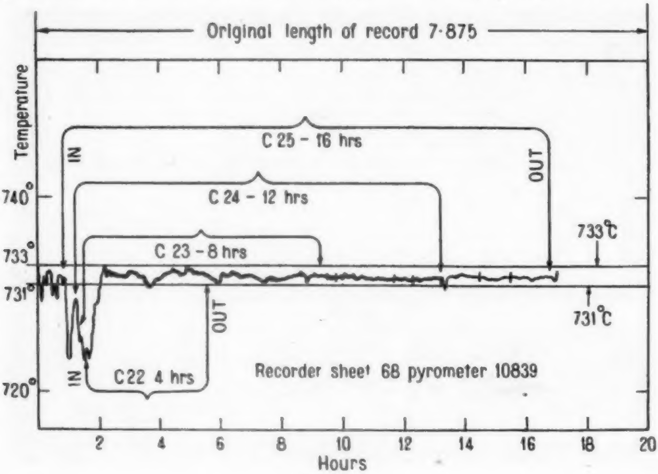


Fig. 6.

of 20° C. On the recorder chart $\frac{1}{8}$in. represented 10° C., which allowed of moderate accuracy. In many cases the error did not exceed 2 or 3 degrees, and it rarely reached 6 or 7 degrees.

Of greater importance were the second furnace temperatures and the single-heat temperatures of 706°, 718°, 725°, 732°, and 739° C., also the falling temperatures and the standard hardening temperature of 760° C. All of these were shown by a platinum resistance thermometer and a Callendar Recorder. Each Centigrade degree was represented by a length on the chart of fully $\frac{1}{8}$in., which allowed of very accurate readings. These temperatures were usually correct within 1 or 2 degrees, and probably the error rarely exceeded 2 or 3 degrees, even for a short time. A typical recorder sheet, reproduced in fig. 6, showing the

temperature record for cutters C22 to C25 (see Table I.), gives confidence in the precision of working. Another recorder sheet is shown in fig. 7 giving the temperature record for cutters 93 and 97. It will be seen that the fall in temperature for cutter 97 took place with great uniformity, from 740° to 706° C. in 12 hours (see Table VI.).

Standard Hardening Treatment.

At a certain stage in the research a uniform treatment for hardening was adopted. This is referred to as the "standard

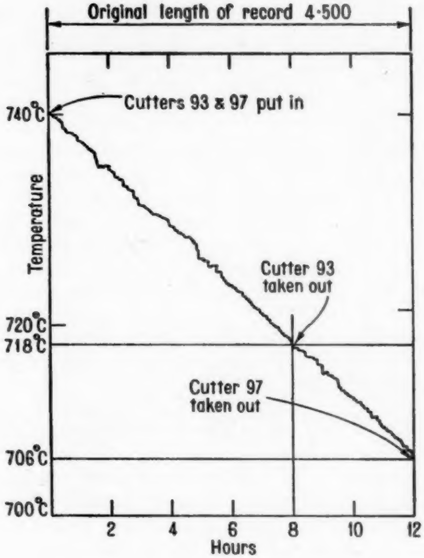


Fig. 7.

hardening treatment," which was carried out as follows:—The test cutter was heated direct from the cold in a salt bath at 760° C. for fifteen minutes; it was then removed with a hook and quickly placed in a wire basket with the hole vertical and the thick end downwards. The basket was plunged into water at a temperature of about 10 to 13° C., so that the top of the cutter was about four or five inches below the surface, and it was then moved sideways, to and fro, for about ten seconds. The horizontal motion was about 18 inches and occupied about one

second in each direction. After ten seconds (five double strokes) the cutter was still warm to the hand, and was allowed to remain in the water for another twenty seconds with very little motion. It was removed from the water in about half a minute from the time of entering it. Many of the cutters cracked before they left the water, some of them breaking in two round the recess. In some cases the teeth continued to click for hours, and occasionally for days. A few cutters jumped in two a quarter of an hour or more after they had been hardened. It must be remarked that whilst this hardening treatment is rightly described as drastic because it offered every facility for breakage, yet it produced an exceedingly good hard cutting edge.

Early Experiments and a Remarkable Result.

For some years in the early stages of this research attention was mainly concentrated upon the hardening of test cutters after they had been machined. They were annealed in many ways. Cutters, both annealed and unannealed, were heated and quenched by hundreds of treatments which, in all cases, were fully recorded with the results arising therefrom. It was found possible to harden the cutters with considerable success and by treatments which differed greatly one from another, but, unfortunately, the most successful treatments demand such accuracy of manipulation as to limit their usefulness, or they did not produce the best cutting edge. Meanwhile, $2\frac{1}{8}$in. bars of this steel were being received every few weeks in the ordinary course of manufacture, and from each bar a test cutter was made and subjected to the standard hardening treatment, which was so drastic that the cutters always broke, but the value of the trial lay in the fact that there were in their behaviour great differences significant of the condition of the steel.

On one occasion a remarkable result was obtained. A test cutter taken in the ordinary way from an annealed bar as received from the steelmakers was found, after being heated and quenched as usual, to have hardened perfectly without a flaw. The pyrometer had been properly standardised and there could be no doubt that any variation between the treatments given to this and all other similar test cutters was so slight as to be negligible. This unusual behaviour must have arisen because the particular bar in question was different from the general run of bars and yet there was apparently nothing to distinguish it from the others. All the bars, including the one in question, were very uniform so far as the machining properties were concerned. They were similar under the microscope and under recognised chemical and physical tests. The appearance of the fracture both before and after hardening was excellent and such as would be taken universally to indicate good steel well treated. The fact that

a remarkable cutter had been produced from it appeared to be the only means by which the bar could be distinguished. The significance of this occurrence could not be overlooked. The bar referred to had, like the others with which it was compared, been made by one of the best Sheffield steel firms in the ordinary course of manufacture, and yet it is safe to say that not one bar in a hundred has the properties which it possessed.

Comprehensive Scheme for Research on Annealing.

As an outcome of the remarkable result described above, the author decided to pursue the investigation further. A carefully planned and comprehensive scheme was drawn up according to which a large number of annealing processes were to be given to the blanks from which a further series of cutters would be made. The annealing process was to be the only variable, and it was to be applied in each case to the blank and not to the cutters after machining. After the specified annealing the blanks were to be machined exactly alike so far as possible, and every one of the cutters so made was to receive the standard hardening treatment already described, which treatment was to be carried out with the greatest attainable accuracy both as regards the heating and quenching of the cutters.

Inasmuch as hardening difficulties are sometimes caused by machining stresses, care was taken to ensure that such stresses should be approximately equal in all cases; for example, the cutter which milled the teeth of the test cutters was sharpened after doing a specified amount of work, and long before it was dull and really in need of sharpening. Precautions were taken in every way that could be thought of to ensure that, so far as possible, every blank should be treated alike, both as regards machining and hardening, and this was done in order that the "strangely discordant results" which were confidently looked for might be attributed with reasonable certainty to the annealing of the blanks.

Description of the Experimental Work.

The total number of blanks made for this series was 102. They were sawn from $2\frac{1}{8}$in. round bars specially made, all from one ingot, and there was good reason to believe that there was no serious variation amongst them as received from the steel-makers.

Two of the blanks were machined in the ordinary annealed condition exactly as received, and the cutters so made were subjected to the standard hardening without any other treatment whatever, with the result, as confidently expected, that they both broke badly.

The remaining 100 blanks were all normalised alike by heating to 825° C. in the salt bath for one hour, and then cooling out in air. It was supposed that at this temperature all, or nearly all, of the cementite would go into solution. After this uniform treatment any difference there may have been in the conditions of the blanks could only be slight, and it is reasonable to assume that the differences which were ultimately found in the cutters made from them must have arisen in the annealing subsequent to the normalising. Two of the normalised blanks were, without any other treatment, machined up into cutters, and these on hardening both broke badly, as was of course inevitable under the given conditions.

Each of the remaining 98 normalised blanks received a different heat treatment, followed by cooling in sand under specified conditions. In a few cases the blanks were simply heated for various lengths of time to a temperature at or below the hardening point. Most of the blanks, however, were first heated for an hour to a temperature of 750°, 800°, 850°, or 900° C., and were then transferred as quickly as possible to a second furnace which was already settled at a temperature below the hardening point, and the soaking in the second furnace was continued for times varying from one quarter of an hour to 16 hours. Inasmuch as the second furnace was maintained at a lower temperature than the first, it would be strictly correct to speak of the pieces as being heated in the first furnace and cooled in the second. Four blanks not shown in the tables were simply heated for one hour to 750°, 800°, 850°, or 900° C. respectively, and cooled out in sand without any soaking or slow cooling below the change point, Ac 1, 2, 3, and all of the four cutters made from these broke badly in the subsequent hardening.

After the cutter blanks had been annealed as described above, Shore and Brinell tests were made in every case, and in addition a record was made when the blanks were being machined into cutters of the machining properties of each blank. The boring and turning were carried through by an experienced turner, who assigned to each blank a "Machining number," according to the ease or difficulty of working. These numbers were given without any knowledge of the Brinell or Shore figures, and were found in some cases not to run parallel with them. The machining numbers may be taken as indicating the grade of the steel from the point of view of a piece-worker engaged upon it. There were six grades, of which No. 1 was the softest, and six blanks which came within this group were machined with conspicuous ease, leaving a good smooth surface. Seventeen blanks, which were classed as No. 2, included those which were used exactly as received from the steel makers. These all machined easily and behaved just as is expected of ordinary well-annealed steel. Nos.

3, 4 and 5 were assigned to blanks in which the machining difficulty increased by slight steps. The blanks which were machined after normalising were included with others in class No. 6. They were harder than would be accepted commercially for annealed steel, although by running at a slower speed even these blanks could be machined without serious difficulty.

Following upon the heat treatment, the hardness testing, and the machining of the blanks, all the cutters so produced underwent the standard hardening treatment already described.

The above may be summarised by saying that for the series of experiments under review :—

1. 2 test cutters were made from blanks as received from the steel maker, and both broke badly on hardening.
2. 2 test cutters were made from blanks which had been normalised only, and both broke badly on hardening.
3. 98 test cutters were made as follows :—
   a. Blanks normalised all alike.
   b. Blanks heat-treated variously (no two alike).
   c. Test cutters hardened all alike.

   These cutters varied greatly in their behaviour on hardening, and this variation must be attributed to the heat treatment to which the blanks had been subjected before they were machined into test cutters.

General Survey of the Results.

Table I. shows that all the three test cutters which, in the blank, had been annealed at 739° broke badly, the defectiveness number being about 60. Some of the cutters made from blanks annealed at 732°, 725°, or 718° C., were quite good, and cutter 43, which, in the blank, had been at 718° for 16 hours had a defectiveness of only four, which means that for practical purposes it was a perfect cutter.

Table II. refers to cutters which, in the blank, had been heated to temperatures varying from 750° to 900° C. and then soaked for various times at 732°, which was distinctly below the hardening point. It was found that at 732° the recalescence could make very little progress, even in twelve hours, and all the cutters broke badly on hardening, with defectiveness figures of about 60 or more. There was nothing to choose amongst them and those made from blanks which had been raised only to 750° in the first furnace were as bad as those made from blanks which had been at 900°.

Table III. refers to cutters which, in the blank, were raised in the first furnace to temperatures varying from 750° to 900° C., and were then maintained in the second furnace for various times at 725°, and it was found that with prolonged soaking the

TABLE No. I.*

Heat Treatment.					
Temperature °C.	Time—Hours.				
	1.	4.	8.	12.	16.
739	13 (60)	14 (57)	—	15 (65)	—
732	21 (74)	22 (51)	23 (8)	24 (12)	25 (26)
725	31 (81)	32 (71)	33 (6)	34 (6)	35 (13)
718	—	—	—	42 (15)	43 (4)

TABLE No. II.*

Temperature in first furnace for one hour °C.	*Time (hours) in second furnace at 732°.* All the blanks were heated alike for one hour in the first furnace to the temperatures shown and were then transferred as quickly as possible to the second furnace which was already at 732°C.		
	1.	4.	12.
750	54 (72)	55 (88)	56 (70)
800	108 (85)	109 (74)	110 (84)
850	166 (65)	167 (63)	168 (71)
900	218 (62)	219 (57)	220 (68)

TABLE No. III.*

Temperature in first furnace for one hour. °C.	*Time (hours) in second furnace at 725°.* All the blanks were heated alike for one hour in the first furnace to the temperatures shown and were then transferred as quickly as possible to the second furnace which was already at 725°.				
	¼.	1.	4.	12.	16.
750	66 (76)	67 (23)	68 (69)	69 (69)	70 (11)
800	119 (72)	120 (71)	121 (77)	122 (26)	—
850	177 (64)	178 (73)	179 (72)	180 (11)	—
900	229 (62)	230 (58)	231 (74)	232 (5)	—

* The plain numbers refer to cutter blanks which, in the first place, were all normalised alike by heating to 825°C. for one hour and cooling in air; then came the heat treatment shown above followed by cooling in sand, and finally all of them (after machining into test cutters) were hardened alike by heating to 760°C. and quenching in water. The numbers in brackets are the "defectiveness marks" assigned to the cutters after hardening.

recalescence made considerable progress and the steel reached a condition moderately good for subsequent hardening; for example, the defectiveness of cutter 70, made from a blank which had been heated to 750° and then soaked for 16 hours at 725°, was 11. Cutter 180, made from a blank heated to 850° and soaked at 725° for 12 hours, was also 11. The defectiveness of cutter 232, made from a blank heated to 900° and soaked at 725° for 12 hours, was only 5.

Table IV. deals with cutters which, in the blank, were raised to various temperatures from 750° to 900° and then maintained in the second furnace for various times at 718°. Here again it was found that prolonged soaking at 718° allowed the recalescence to take place in such a manner that the steel reached a condition good for subsequent hardening. Cutter 82, made from a blank heated to 750° and then soaked at 718° for 12 hours, had a defectiveness of only 3. The Brinell number of the blank was 196, Shore 32 and machining test No. 1. Cutter 135, made from a blank heated to 800° and soaked at 718° for 12 hours, had a defectiveness of 6, and machining No. 2. Cutter 246, made from a blank heated to 900° and soaked at 718° for 16 hours, had a defectiveness of 5, and machining No. 2. The cutters made from blanks which were cooled to and maintained at 718° for only four hours or less all broke more or less badly, though cutter 81 (750° 1 hour and 718° 4 hours) had a defectiveness of only 18, and the machining number was 1.

Table V. shows cutters which, in the blank, were heated in the first furnace to temperatures varying from 750° to 900° C., and were then maintained in the second furnace for various times at 706°. The maximum time at 706° was only two hours because it was supposed that any change likely to take place would be rapidly accomplished at this low temperature, and it was improbable that further important changes would take place by prolonged soaking at 706°. Every cutter in this series broke badly on hardening, showing that when the recalescence is accomplished so rapidly, as was the case in these blanks, the steel does not reach the desired condition. The defectiveness throughout was about 60 or more except for cutter 141, which showed only 37 when it was expected to be about 70.

Table VI. shows cutters made from blanks which were first heated to temperatures varying from 750° to 900° and were then transferred to the second furnace at 740°, but instead of being maintained at 740° the temperature in the second furnace was made to fall at a uniform rate from 740° to 718° or to 706°, as the case might be, in the times shown. All the cutters made from blanks in which the temperature fell only to 718° broke badly with the exception of cutter 93, which, after being heated in the blank to 750°, was made to cool from 740° to 718° in eight

TABLE No. IV.*

Temperature in first furnace for one hour. °C.	*Time (hours) in second furnace at 718°.* All the blanks were heated alike for one hour in the first furnace to the temperatures shown and were then transferred as quickly as possible to the second furnace which was already at 718°C.				
	½.	1.	4.	12.	16.
750	79 (74)	80 (21)	81 (18)	82 (3)	—
800	132 (63)	133 (57)	134 (27)	135 (6)	136 (12)
850	189 (65)	190 (79)	191 (24)	192 (38)	—
900	242 (64)	243 (68)	244 (78)	245 (14)	246 (5)

TABLE No. V.*

Temperature in first furnace for one hour. °C.	*Time (hours) in second furnace at 706°.* All the blanks were heated alike for one hour in the first furnace to the temperatures shown and were then transferred as quickly as possible to the second furnace which was already at 706°C.		
	½.	1.	2.
750	87 (76)	88 (81)	89 (69)
800	141 (37)	142 (86)	143 (62)
850	197 (88)	198 (73)	199 (69)
900	251 (58)	252 (72)	253 (70)

TABLE No. VI.*

Temperature in first furnace for one hour. °C.	*Time (hours) in second furnace cooling from 740° to 718° or 706° as below.* All the blanks were heated alike for one hour in the first furnace to the temperatures shown and were then transferred as quickly as possible to the second furnace which was already at 740° and which then began to fall in temperature at an even rate.					
	To 718°.				To 706°.	
	In 1 hr.	In 2 hrs.	In 4 hrs.	In 8 hrs.	In 3 hrs.	In 12 hrs.
750	—	92 (70)	—	93 (14)	96 (21)	97 (5)
800	148 (61)	149 (59)	150 (90)	151 (55)	154 (70)	155 (1)
850	—	202 (72)	—	203 (76)	206 (81)	207 (50)
900	—	256 (55)	—	257 (59)	260 (58)	261 (57)

* The plain numbers refer to cutter blanks which, in the first place, were all normalised alike by heating to 825°C. for one hour and cooling in air; then came the heat treatment shown above followed by cooling in sand, and finally all of them (after machining into test cutters) were hardened alike by heating to 760°C. and quenching in water. The numbers in brackets are the "defectiveness marks" assigned to the cutters after hardening.

hours, and in this case the defectiveness number was only 14. Some of the cutters, however, which were allowed to cool to 706° were good, and this must be attributed not to the fact of reaching so low a temperature as 706°, but that they had a longer time in the range at and immediately below 718°, during which the desired change was taking place. Cutter 97, made from a blank heated to 750° and then cooled during 12 hours from 740° to 706° had a total defectiveness of 5, but whilst the Brinell and Shore tests showed that the blank was very soft, the machining number curiously enough was so high as 4. Cutter 155, made from a blank heated to 800° and then cooled during 12 hours from 740° to 706°, had a defectiveness of only 1. The Brinell figure for the blank was 187, Shore 30, but the machining figure was No. 3.

The hardening treatment throughout the whole series was, as already explained, constant, and very little difference was found in the hardness of the cutters, no matter what the annealing treatment of the blanks had been. The Brinell figure throughout was over 700 and the Shore figure was about 92 to 95.

The Annealing Range.

From a general inspection of all the results obtained from these cutters it is evident that there is a range of temperature, somewhere about 715° to 728° C., within which, with prolonged soaking, the steel under consideration reaches a condition in which the liability to hardening cracks is reduced to a minimum. The range may be the same for heating and for cooling if the process be sufficiently prolonged, but this is doubtful. For practical purposes and with limited time the range may be taken as a trifle higher for heating than for cooling; that is to say, that if the blanks are merely heated up to, and soaked at, a temperature which gives the best results, that temperature will be found to be a few degrees higher than would be allowable if the blanks were first heated above the change point and then cooled to and soaked at a temperature within the annealing range.

It has been mentioned that the blanks, after the heat treatment, were all cooled slowly in sand, but it is a striking fact that many of the blanks in which the change had occupied a long time, and was fully accomplished, would have been almost as soft if they had been quenched out in water. Table VII. shows the hardness of some bars of the steel under consideration which were heated in pairs alike, but one of each pair was sand-cooled whilst the other was water-quenched. It will be seen that the extra hardness caused by quenching was slight and in some cases negligible. B30 and B35 were both heated exactly alike to 725° C., and soaked at that temperature for 16 hours. The only difference between them was that B30, quenched in water, gave

Brinell hardness of 201 and Shore 33; whilst B35, cooled in sand, gave Brinell 197 and Shore 32. It is probable that the annealing of this steel has not been properly accomplished if the fact of quenching from, say, 700° C. causes an appreciable hardening.

Heating Above the Annealing Range.

It is worthy of notice that blanks which have been soaked for sufficient time within the limited range below the change point are capable, when made up into cutters, of good hardening so far as cracks are concerned, even though the temperature in the first furnace may have been so high as 900° C. It should be stated, however, that another series of trials made with bending test bars of similar steel showed that a preliminary heating to 900° impaired the strength of the steel. Bars which were not subjected to a higher temperature than 750° in the heat treatment gave very good results under bending tests, and in some instances equally good results were obtained from bars which had been heated to 800° and even to 850°.

TABLE No. VII.

No. of Bar.	First Furnace.		Second Furnace.		Quenching or Cooling.	Hardness.	
	Temperature °C.	Time Hours.	Temperature °C.	Time Hours.		Brinell.	Shore.
B. 30	—	—	725	16	Water	201	33
B. 35	—	—	725	16	Sand	197	32
B. 39	—	—	718	16	Water	207	34
B. 43	—	—	718	16	Sand	197	32
B. 78	750	1	718	12	Water	179	30
B. 82	750	1	718	12	Sand	170	26
B. 131	800	1	718	16	Water	187	30
B. 136	800	1	718	16	Sand	179	29

Proposal for Standard Hardening Test.

Tool steel which is entitled to rank as thoroughly good, according to all recognised tests, may still vary greatly with regard to the liability of articles made from it to warp or crack in hardening. It is desirable that there should be a recognised standard of hardening behaviour which might be specified and

verified as easily as the analysis or the tensile properties. Hardening tests might be carried out cheaply and quickly by means of discs or bars of given sizes, jig-drilled in such a way as to render various parts liable in different degrees to hardening cracks. There might be an extremely awkward part in which a crack could hardly be avoided and there might be gradations up to a point at which a crack would indicate something particularly bad in the steel. If such a standard piece were subjected to a specified heating and quenching, its behaviour would be an invaluable indication of the condition of the steel. It might be that one or two cracks in the most difficult portion would be allowable in the case of steel used for ordinary work, but that further cracks would indicate that the steel was not yet in the best condition and required a further treatment before being fit for use.

Need for Theoretical Discussion.

It may be objected that the work described in this paper is not of scientific value because it is not based upon a well-supported theory. The research may be regarded as no more than empirical groping with no guidance except the observed results. The author acknowledges the force of the criticism, and can only say that theory after theory has presented itself to him without proving adequate as an explanation of the results recorded above. The fact remains that if the annealing of a representative tool steel, such as the author has dealt with, be prolonged for sufficient time within a certain limited range of temperature, the steel reaches a condition in which it will respond to a given treatment with reasonable certainty instead of giving those strangely discordant results which, by their frequency and elusiveness, have created the impression that they are beyond remedy.

Although the main constitutional changes which take place at the recalescence are well known there is still much that is indefinite. The author believes that whilst the actual hardening change is more closely defined, the complete change takes place over a range of temperature covering perhaps a dozen Centigrade degrees; that is to say, that if the steel be heated to the lowest point at which a definite change becomes manifest, the complete change cannot be accomplished without a further raising of the temperature by a dozen degrees or so. A rise of only half a dozen degrees beyond the lowest point at which there is a recognisable change would probably never effect the complete change, no matter how long the heat were continued.

If 20 small pieces of steel were thoroughly tested after being heated to exact temperatures varying in steps of only one degree from 720° to 739° C. for, say, 10 hours in each case, followed by swift quenching in ice and brine, it is probable that the

progress of Ac 1, 2, 3 could be traced, and it may be that the change in heating could be divided into definite stages. A similar experiment in cooling might be used for the investigation of Ar 3, 2, 1.

There are many possibilities for trifling variations in treatment to produce variations in results which, though slight, may be of vital importance. The changes occurring at Ac 1, 2, 3 are inadequately described by a general statement that *alpha* iron changes to *beta* iron, whilst at the same time the proportion of cementite necessary to form a eutectiod composition passes into solid solution. Carbide (Fe_3C) may go into solution as carbide, or it may be dissociated into iron and carbon, and if it is dissociated it may, if time be allowed, pass through the stage Fe_6C. There may be conditions under which Fe_2C is formed. The carbon itself may, under certain conditions at a high temperature, assume allotropic forms capable of being held in suspension or in solution. Whilst the author believes that Ac 1, 2, 3 requires a range of temperature for its completion, it may be supposed that there is a definite temperature at which *alpha* iron changes into *beta* iron, and though this temperature may be varied by the presence of other elements it may still be sharply defined. If the temperature of the steel be raised until it is not more than a degree or two higher than the point at which the *alpha* iron changes, it is possible that the newly formed *beta* iron, perhaps with nascent properties, has a different action and reaction on cementite from ordinary *beta* iron which has been quickly constituted by a swift passage through the change point.

Obviously, there are endless possibilities for speculating on all the changes that may occur at the recalescence of tool steel, but there is little experimental evidence to go upon, beyond the fact that when the change either in heating or cooling is brought about at a very slow rate and within a certain very restricted range of temperature, remarkable results are obtained. It may be that an explanation has not been found merely because of its simplicity, and that the steel reaches a desirable condition when the change takes place so slowly as to allow of a perfectly even distribution and arrangement of all the constituents under conditions which do not conduce to segregation.

Annealing Under Workshop Conditions.

It might be supposed that the work dealt with in the foregoing pages requires special furnaces and delicate apparatus such as can only be found in a laboratory, but the author is prepared to maintain that it is practicable to control the processes within the required limits under workshop conditions, and with the ordinary labour available. The method of heating in a liquid bath for annealing and for hardening can readily be carried out

with a degree of precision which is surprising to those who have not been accustomed to it, and the control of the temperature is all the easier when a large mass is being dealt with, provided that the heating is done by gas, which gives the operator the means of controlling the temperature to a nicety.

Conclusions and Acknowledgments.

The object of this paper has been to direct attention to the neglected possibilities in the annealing or heat treatment of carbon tool steel. The results given above represent only a small fraction of the matter available. The statements about the annealing range are put forward with confidence because they have a broader basis than the single series of experiments described. They must be taken as the outcome of experiments and observations extending over many years. The research was devoted to one particular steel, which was chosen because it is largely used for certain classes of work, and the author was specially familiar with it, but there is no reason to doubt that tool steels covering a wide range would respond in a similar way. The author believes that an annealing treatment which would practically eliminate the risk of distortion or breakage can be found for ordinary tool steel. If this were done the hardener would have no need, as now, to modify the hardening treatment for fear of warping or cracking. He would have confidence to heat and quench his work regardless of any consideration but the production of the best possible cutting edge or wearing surface, and this would lead to a great increase of efficiency, in addition to the direct saving effected by the prevention of hardening cracks.

The author has pleasure in recording his thanks to his brother, Mr. E. Russell Brayshaw, who has shared in the whole of the work, also to the Iron and Steel Institute, and the Liverpool Engineering Society, for permission to reproduce passages which have appeared in papers presented to them.

THE DISCUSSION.

MR. L. WILD (Messrs. Automatic and Electric Furnaces, Ltd.) congratulated the author on the ability which he had shown in conducting the experiments referred to in the paper, and felt sure that he would find himself very well repaid for what he had done. There were two points that were specially interesting in the paper; one was that it was possible by very slow cooling at somewhere about the middle of the recalescence point, greatly to reduce the chance of cracking in subsequent hardening, whilst the other point was that before annealing was carried out, he raised the temperature to 900° without cracking taking place after the annealing. With regard to the second point, he himself carried out experiments years ago on annealing at 900° and other temperatures, and he found that after subsequent hardening in a standard treatment, the overheated steel besides being nothing like so strong as that which had been annealed at 750° was also very much more ductile. It seemed to him that when the expansion came in in subsequent quenching, the one was likely to counteract the other, and that perhaps was the general explanation of that overheated steel before annealing. Although it might spoil the steel of the tool eventually, it was quite harmless as regards cracking.

He had found that magnetic testing was very useful in this sort of experiment. For instance he found that if he heated two or three specimens of steel up to various temperatures from 750° to 1,000° and quenched them right out, he got a decreasing magnetisation as the temperature increased. It was a perfectly straight line starting from the decalescence point upwards, but if he went to a higher temperature and then down again in the furnace before quenching, although there was a considerable amount of grain growth and an alteration in some of the magnetic properties of the steel, the saturation intensity of magnetisation was perfectly reversible. This indicated that the steel as soon as it got past the decalescence point went from one description of austenite into another description of austenite. For many purposes he himself disregarded the usual terminology of the metallurgists because there were not enough terms in it for him and he called these F material and G material respectively. The higher the temperature the more G material he got, and after it was quenched it cracked. If he let the temperature down again he got exactly the same results as if he had not passed the 750° temperature, and he got the F material and no cracks. At the same time, at the lower temperature he got grain growth and a change in coercive force which was really a sort of measure of grain size, amongst other things.

The effects of long annealing were not so simple. When this matter was first brought up by Mr. Brayshaw four years ago at the Iron and Steel Institute, the metallurgists kept absolutely silent and yet the thing ought not to be so very difficult to work out.

There were one or two suggestions and lines of investigation which occurred to him. The steel might be strengthened so that it would stand a greater bursting force, or it might be made more ductile so that it would not crack. These two things ought to and could be investigated in a mechanical laboratory. The steel might become a poorer conductor of heat and he was convinced from experiments he had carried out from time to time, that one of the effects of all descriptions of heat treatment was to alter the conductivity of the steel to heat. It certainly altered the electrical resistance. Unfortunately, thermal conductivity was extremely difficult to measure, especially when the material was hot. It was necesary to have a temperature gradient but electrical conductivity was a sort of substitute. Unfortunately, however, one could not feel certain that the two things would go together, although as a rule they did. Some light might be thrown on these points by carrying out electrical resistivity tests.

The thermal conductivity would affect the question in this way: when a steel was given a normal heating and cooled very slowly, there was an expansion at a temperature round about 700°. It was a recalescence point. The steel was then very plastic and consequently no strain or stress was set up and it did not harden. If the steel were quenched in oil there was still the expansion at about the same temperature. Owing to the quickness of the cooling, however, the stress set up was sufficient to cause some strain and hardening. A sort of semi-hard condition resulted, due to the strain, but the steel did not fully harden. If we went a stage further and quenched in warm water, the expansion was partially or totally suppressed. There was another expansion or delitation, as the French people called it, at about 350°, and that was the expansion required in hardening. The steel was then not sufficiently plastic to allow of the hardness, and yet it was sufficiently plastic to allow a certain relief to the strain. If they went a stage further and quenched in very cold brine, that expansion was very nearly, although not entirely, suppressed. When quenching in cold brine there was a third expansion, the Ar. 3 point somewhere between 100° and 150°. It spread over a considerable range and it was very difficult to measure with accuracy. It was here that cracking occurred because the steel was not sufficiently plastic. At any rate that was his explanation of it. It was in investigations of this sort that magnetic testing came in again because the expansions were extremely difficult to measure by other means. He had found that when steel was in its least magnetic condition, the second expansion took place, *i.e.*, the Ar. 2 point, and it was more magnetic when it was quenched in colder water or hotter water. He suggested it would be useful to carry out investigations on some such lines as these, namely, if we could have a set of specimens and half of them, as blanks before being turned, were treated by Mr. Brayshaw's method and the other half were not so treated. If the two sets were heated in pairs to make sure the heating was exactly the same and quenched in pairs in water at various temperatures, it should be possible to find out from the magnetic results obtained whether after Mr. Brayshaw's annealing treatment they were quenched more on the Ar. 2 and less on the Ar. 3

point. He suggested that if the steel after this treatment had a lower thermal conductivity, there would be less of the Ar. 3 and more of the Ar. 2. It was very possible that both these points changed together after that treatment, but it would be interesting if investigations on these lines could be carried out with a mechanical laboratory to do the mechanical testing, a physical laboratory to do the thermal testing, and an electrical laboratory to do the magnetic and electrical resistance tests. In that way he thought they would be able to get to the bottom of this problem. If the author would co-operate, he himself was willing to do his share on the electrical and magnetic side, although it was going to be rather a tiresome business for all of them.

Mr. Brayshaw, replying, said the point made by Mr. Wild about the magnetic property being the same whether quenching was carried out on the way up from 750° or on the way down to 750°, was very interesting and very remarkable and not what would have been supposed. He would have thought that the hardness would have been the same, but that the wearing properties and cutting properties would have been much worse when quenching on the way down, if the steel had been a long time at 900°. In order to get something extremely hard and good also in magnetic properties, the result depended very much on the size of the piece of steel. If a piece of steel were four or six inches long and were heated first of all in a liquid for two minutes at 740° and then quenched out, extreme hardness would result. It was impossible to heat steel too quickly in order to get good results. The old-fashioned method was to heat slowly, but that was a mistake. What was meant was that we should not overheat, and because it was generally impossible to heat quickly without overheating the advice was to heat slowly. Therefore, if they heated steel quickly up to 850° or 880° for a short time—and two minutes for a piece of steel four or six inches long would do no harm—it could be got down to 740° and then quenched, and it would give wonderful results both magnetically and as regards hardening. Dr. Hadfield, of Sheffield, had done a fair amount of work on electrical conductivity; he had seen many of his results, and it was possible to test hardness by electrical conductivity. That was often done, but he had not before heard of thermal conductivity being used in this way; it seemed a matter of very great interest. He certainly would like to collaborate in following this matter up, although at present he found it very difficult to give any time to research work. It was not as if one had a laboratory and a staff to do it. It all meant money, and most of those engaged in business had their time fully occupied in conducting their businesses as best they could, but if the opportunity arose he certainly would like to follow the matter up.

Mr. E. W. Hancock (Member) asked the author, in connection with the cutting of metal, if he really thought carbon steel was worth all the trouble indicated in the paper, having regard to the use of high percentage tungsten steel for very heavy duty in removing metal. Some extraordinary results were achieved with about 18 per cent. tungsten steel, and his experience was that the best results were given by that steel in the ordinary cutting of metals to-day.

Mr. Brayshaw agreed with Mr. Hancock in what he said as to the value of tungsten steel, but added that, without in any way pushing carbon steel in competition with tungsten steel, there is a field still for carbon steel. There were some things for which no other steel was applicable, and it was only in cases where carbon steel must be used in any case that it was worth the trouble that was being taken with it. There were many press tools, etc., for which carbon steel must be used, besides many other applications. When it was possible to use 14 or 18 per cent. tungsten steel, they should by all means do so.

Mr. H. S. Locker (Member of Council) put it to Mr. Brayshaw that the test cutters referred to in the paper were made in rather large quantities, and were really designed with the idea that they should crack. In commercial work, in making tools, that was hardly the case, and it was, of course, common knowledge that if a cutter were not properly designed it would crack, and it would be wasting time to work with it. Would any great number of the cutters referred to in the paper have given good commercial results in cutting?

Mr. Brayshaw said that the cutters were, of course, made with a view to their cracking, as remarked, but it was very much the same thing as testing bars. For instance, there was the notched bar, in which the notch was used in order to make the bar break, but something was learned by doing so. The same applied to these cutters. It was quite true that the experiments covered an extreme case, because he wanted the cutters to break if there was any possibility of them doing so at all. If he had taken a good design from the point of view of a cutter, he would not have learned very much, and it was only by taking the more difficult cases that information could be obtained. At the same time, he did wonder, perhaps, whether he had made up a difficulty, and he might have had a larger percentage of good cutters if he had not taken such an extreme case; but the idea was that there should be every temptation for the cutter to break.

Mr. C. Whitaker (Member), referring to the commercial value of these experiments, called attention to Table VI., and pointed out that after twelve hours' annealing the best results were obtained at 750 to 800 deg., falling to 706 deg. in twelve hours. It was, however, rather an expensive proposition in ordinary work to anneal every piece of steel cut from the bar for that time, and he was wondering whether this was not more a matter for the steelmakers to deal with, seeing that the blank was annealed, than for the individual users. It was not a matter of annealing after the machining process, but annealing in the blank before machining.

Mr. Brayshaw expressed his satisfaction that this point has been brought out, because it was a very important matter. The steelmaker should do the annealing, but he would never do it unless he were compelled. It was necessary to bring pressure to bear on the steelmaker to give better material. With regard to Table VI., it must be remembered that of the 12 hours from 740 to 706 deg. the valuable period was in the middle of the 12 hours; practically nothing happened for the first four hours, then the real work was being

done in the next four hours, and nothing in the remaining four hours. Twelve hours was a long time for annealing, but the point was that the steelmaker does it; he spends 10 to 20 hours, starting at a high temperature and going down to a low temperature, whereas the effective part of the annealing was for a much less period of time from the point of view of getting the steel into a condition for subsequent hardening, as distinct from the mere fact of making it so that it was soft enough to be machined. The great thing, of course, was to get the steel right to start with and then the rest followed quite easily. Many people spoke about overheating, warping and cracking in hardening without any real experimental basis, and they were not certain of what they were doing. The great thing was to bring heating under control so that we could prescribe with certainty the heat treatment to be applied. What we wanted above everything else was to be able to write down a heat treatment in such a way that it could be sent to Australia with every confidence of the results being the same as if the treatment were carried out here. At the present time it was known that an analysis carried out in Australia would give the same results, within recognised limits, as the same analysis carried out in this country, and we ought to be able to do the same with heat treatment. Then the results of their own treatment could be put side by side with the results obtained by the steelmakers for comparison.

Mr. Locker remarked that he believed this was done now to a certain extent. For instance, Messrs. Kayser, Ellison & Co. sent out instructions as to heating, and he had got remarkable results with most amateurish methods on their KE 805 steel simply by following their instructions. The same steel can be used for different purposes by varying the treatment a few degrees.

Mr. Brayshaw said he had used some thousands of pounds' worth of Kayser Ellison steel, and what Mr. Locker had said was quite true, but even so, the steelmakers did not know all they ought to know about steel or all that the user had the right to expect them to know.

Mr. Locker said that one of the best properties of the steel mentioned was that even in the hardened state it was ductile to a certain extent; it had good wearing properties without being what might be termed hard.

Mr. Zieshang (Member) said he had had rather an extended experience with hardening generally for springs, although he had not had much to do with cutters until recently. He had had some steel from a very renowned Sheffield concern for rather large cutters, and 5 out of 15 cutters broke to start with. He, therefore, looked round to see what could be done to improve matters. It was probably common knowledge to everybody, although it might be worth mentioning, that water cooling largely depended on the volume of water. For instance, he found that with a 10-gallon bosh, cracking took place extensively, but with a 2½-gallon bosh and just whisking the cutters about, each one having its own cooling point, it was found that the cutters were very much more reliable, and many of them treated in this way were good to-day. He learnt this point in the surgical instrument business where the material used was all

cast steel. It was essential with these instruments that the steel should be just tough hardened. The instruments were each put into a definite amount of oil in a separate little pot, the oil being rather salty. Perhaps similar methods with cutters would give better results, because it was the volume of liquid that seemed to influence the cracking. It was possible to crack a cutter in a large pan of oil, but not if it were reasonably salt and if the nature of the heat treatment were known beforehand.

Mr. Brayshaw said the point was that a small volume of water heated up and the hotter water had nothing like such a swift quenching action.

Mr. Zieshang: The water was cold to start with in each case.

Mr. Brayshaw said that no doubt using a smaller volume made the quenching action less drastic. Personally he would not have thought it was of very great importance, but it certainly was interesting to know that good results could be obtained by the above method. With regard to surgical instruments, he was surprised that the cooling was done in oil with such tiny implements. Before the war he went to St. Petersburg for the Russian Government in connection with the hardening of surgical instruments. He knew nothing about the particular job, but he went out as a hardener to show them the use of salt baths. He hardened large numbers of forceps and all sorts of dreadful looking instruments which he had never seen before, but he did it all as a matter of heating and purely as a metallurgical problem. He heated the instruments and quenched them right out, and was told that they gave the best results they had ever had out there.

Mr. Zieshang said that in the case of forceps it was the practice to harden them in pairs with the screw loose because of the recessed portion, and unless it was done in the way he had explained a commercial result could not be obtained. In some types of surgical pliers unless this were done, a lot of work would have to be done afterwards in setting and overcoming warping. If the instrument were put into the water straight and pulled out straight, it was bound to be straight.

Mr. Brayshaw said surgical instruments were an example where there was still use for carbon steel. Doctors at present would not look at stainless steel for the work, although one would have imagined that it would have been largely used through being antiseptic. However, doctors preferred to keep to carbon steel and sterilise each time before using the instruments again.

Mr. Locker referred to Table VII. in the paper where illustrations were given of cooling in water for annealing. When he was in Sheffield some years ago, the expert toolsmiths could easily anneal steel by quenching in water after heating in an open fire. It was pure rule of thumb and gauging of the temperature by colour, though these men were probably using more science than they really knew.

Mr. Brayshaw said it was quite true that they annealed in cold water in Sheffield, and they did it by eye. The men, as the result of their experience, could see the recalescence occur. They got the temperature well below, and then quenched in water and allowed recalescence to occur very slowly. That had been known for a very

long time, and a man with a good eye would watch the recalescence in that way. No doubt everybody was familiar with what happened in quenching a bar of steel such as a 5 per cent. or 6 per cent. tungsten. If one took a bar of that steel 18 inches long and heated it up to 780 deg. and then just let it down, it naturally cooled from the ends. When the two ends had become dark the band of darkness crept down the bar and the ends became bright. Then the dark band crept farther in towards the centre and the ends began to get dark again. In this way they had the dark ends, then a bright portion, then a dark portion, whilst the centre had not yet gone dark.

Mr. Worship said the same could be done with high speed tungsten steel. Quenching had a lot to do with the prevention of breakages or distortion for the simple reason that all steels were not alike. Some carbon steels if allowed to remain in water until cold would crack, whilst others could be left in water with safety. Some steels if taken straight out of the salt bath and reheated within 70 deg. of the temperature of the bath for quenching, would never fracture. He himself hardened something like 3,000 or 4,000 tools per week, and the percentage of fracture was not one in 500 when dealt with in this way. That is dealing with tools of all sorts. For press tool work the important thing was to have the steel in the right condition before it reached the users. In those circumstances he had found that to go just above the hardening point was better than going just below. If the hardening point was round about 760 or 780 with a carbon steel, and it were taken to 800 deg., allowed to cool and then hardened, it would be found that all strains and stresses which might have been set up by machining had been taken out of the metal.

Mr. Brayshaw said that no doubt a good deal could be done by suitable dipping at the right time and pulling out at the right time.

Mr. Worship added that in hardening tools commercially one could not afford to take 12 hours for annealing in dealing with 400 or 500 tools a day, and a quicker and safer method was required.

Mr. Brayshaw said that he would like to see hardening done in 3-ton lots or something like that.

Mr. L. Wild said that automatic control was necessary, and that was rather difficult to obtain with coal furnaces which the Sheffield people insisted on using.

Mr. Worship said there was no doubt that a lot of work left to the hardener ought to be done by the steel manufacturers in the first place. In the case of cobalt steel, at the present time a well-known firm gave instructions for three heat treatments, although one was not a heat treatment for hardening at all. There was a heat treatment to 1,150 deg., then another at 750 deg., and another at 1,000 deg. The 1,150 heat treatment, however, if it were necessary, could be done by the steelmakers much more easily than by the user.

Mr. Brayshaw: That is so.

Mr. Worship said it all came down to the point that as things stand at present the user had to put the steel right before he could start.

The Chairman remarked that after all most people bought steel very largely on price, and no doubt if the users got the steelmakers

to give them precisely the steel they wanted, they would still grumble. Hardeners, like other people, had their peculiarities, some more than others. Nevertheless, he felt that it should be possible to get a more uniform bar from the steelmakers, although he was inclined to think that this was being obtained in the newer steels, which could be relied upon to a much greater degree of accuracy than any of the old-fashioned or standard carbon steels. Personally, he felt they ought to begin to drop the standard carbon steel altogether and adopt the later brands of steel for their own particular purpose. In the case of press tools, for instance, there were other alloys of steel than carbon steel which he considered more suitable, and yet they all seemed to stick to carbon steel for this purpose. Messrs. Firth made an excellent brand of oil hardening steel for press tools, and there was a big field for research work on this point, because the Brinell or Shore rating did not always tell what steel was going to be best for wear. There was the resistance to abrasion which was of importance with press tools and many cutting tools, and he did not think there was a satisfactory means or a standard means of measuring resistance to abrasion. This question was taken up during the war by the National Physical Laboratory, but no results were ever published. He believed it was found that, although gauges could be obtained glass hard, they did not wear so well in use as gauges not quite so hard. Then there was another point with regard to steel upon which perhaps Mr. Brayshaw or Mr. Wild could give some enlightenment, and that was that the old Bohler steel and quite a number of other steels made at a similar price before the war had properties much better than many present-day steels. He had been under the impression that that was solely due to the ore that was used in making these particular steels, the ore from different parts of the country varying in a similar way to the coal which was found in different places. He certainly was under the impression that we should use some of the more modern steels, and that if we were prepared to spend the time and money in trying out some of the more modern brands of steel to replace the old-fashioned carbon steel, better results would be obtained. It had to be admitted that the high speed tungsten steels were very much better for ordinary cutting purposes than any of the old carbon steels—no matter how they were hardened. It might be possible, as Mr. Brayshaw had mentioned, to get them very hard by heating them quickly. Although plenty of firms might regard themselves as fairly well equipped with hardening furnaces, many of them did not keep a salt bath, because there was not sufficient use for it in a great many cases, and these firms were generally tied down to one or two types of gas furnace or sometimes coke furnaces. The same thing applied to the magnetic method of hardening. Personally, he had been very interested for years in the magnetic method of hardening, and he believed that eventually it would be developed into a real commercial success; at present he did not think it was. At the moment it was a very expensive method, probably because its use was so very limited compared with other methods. At the same time it was possible to do all sorts of operations more efficiently than in an ordinary gas furnace, and for a lot of work the magnetic method

was undoubtedly the best. When we were in a position to get a sufficiently robust furnace to stand the use which it would get in the ordinary hardening shop—and perhaps it could be combined with the Brearley method of obtaining the recalescence and decalescence points with a hardening furnace—then we should have a method of hardening all kinds of steel providing, of course, it had been given the proper heat treatment beforehand. So far as he could see, the magnetic method was the nearest approach to a really practical method that we had yet got, and he was still hoping that it would be persevered with and further developed.

MR. WILD: It will be.

THE CHAIRMAN: I sincerely hope it will. Continuing, the Chairman said that until the magnetic method could be used in the ordinary run of work, which varied considerably, he did not think it could safely be claimed that the magnetic method was quite a commercial success. There was such a variety of work in the average tool room that it was necessary to stick to the old-fashioned methods at present in a good many factories. Mr. Brayshaw had made a very good point in the paper in stressing heat treatment before hardening. If it were possible to persuade the steel makers to give a better steel, or the same steel in a better condition for hardening than was the case at present, and at the same or a lower price, that would be another achievement, but there it seemed necessary to fight the same feeling that appeared to exist in regard to stainless steel; the chief objection there was price. There was quite a strong feeling that stainless steel when used for table knives would not cut, but the stainless steel knife would cut quite as well as an ordinary steel knife if it were not started too thick and was given the ordinary treatment. He felt strongly that the ordinary carbon steel should be allowed to die quickly, and that the newer steels should be used, because if we had not found during the past 20 years that the steels being used then are inferior to those available to-day, it did not say much for the research work that had been carried on in Sheffield and the other steel centres. He believed that if attention were paid to annealing by heat treatment of the steel—and there was certainly more done in that direction now than there used to be—the war, of course, brought about great developments in that direction—a great deal of progress would be made. Ten years ago many people did not know what this sort of treatment meant. They were very much indebted to the author for his paper and for giving them the opportunity of discussing this subject. Perhaps the author would say whether he had had any experience of different makes of steel or ores.

MR. BRAYSHAW said he knew nothing about different ores, but he knew the old Bohler steel and obtained excellent results with it. He agreed with what the Chairman had said about using carbon steels, *i.e.*, that for press tools, carbon steels should give way to the modern high speed steels, but as a rule the steel used for press tool work was an alloy steel, and could be broadly classed as nearer the carbon steels than the other types of steel. He also agreed with what had been said about using steel suitable for the purpose. A good deal of research work had been done to find out better alloys, and that

research work had been well carried out and had been very successful. The result was that there was a range of steels to choose from. At the same time not enough attention had been given to the treatment of the steel, and that was quite as important as getting the right steel. He himself had been saying for 20 years that poor steel when well treated was better than a good steel badly treated, but that was not to be taken as an excuse for using bad steel. It was necessary to get good steel, and then treat it well. No matter whether a steel was good or bad in the first place, if it were badly treated then it was hopeless.

THE CHAIRMAN said that just before the war he believed the Bohler people brought out a special steel which they called Special K air hardening, and that was about the toughest thing he had ever seen. He had never seen it since, however, and he did not know whether it was produced now. The only drawback was the difficulty of machining. It was worse than the old 3 Star tungsten Diamond, and that was bad enough. The Special K, even in the annealed state, was very difficult to machine, but once it was machined and hardened as a press tool it had an almost indefinite life.

MR. WORSHIP said there were so many variations in carbon steel, and it was even worse now than it was years ago. It was difficult to get one standard steel then, but now there were dozens of varieties.

THE CHAIRMAN said he thought the difference was more apparent because we knew more about steel now. The old methods of hardening covered up a lot of inaccuracies in the steel.

MR. LOCKER said that a few years ago he believed there were two carbon steels generally understood by the average man in the shop, especially in Sheffield, and they were cast steel and chisel steel. The difference was in the percentage of carbon.

THE CHAIRMAN remarked that at one time it was the practice to make the steel hot and put it into water. If it were not then hard it was made hotter and again put into water, and if it was not hard by that time it was regarded as a bad steel.

MR. BRAYSHAW said it was necessary to educate people up to the point of having proper pyrometers and knowing how to standardise them. The position was hopeless unless that were done.

THE CHAIRMAN said this was a very important point. It was still possible to find hardening shops equipped with quite a reasonable outfit of pyrometers, but the people did not know how to use them. It was not at all difficult to find a man using a pyrometer, but quite incapable of making any allowance for variations of cold junction. There was certainly a lot to be done yet in methods of governing the temperatures of furnaces. In many cases pyrometers were used in muffle furnaces, and although the pyrometer and the indicator might be all right, the pyrometer was in such a position relative to the work in the furnace that the temperature was by no means indicated on the indicator. Further, we still need a perfect covering or protection for the pyrometer. That was one advantage of the oil bath, because if a pyrometer was used in an oil bath it was possible to get a much more accurate reading of the temperature of the work. Experiments with regard to hardness and resistance to abrasion might be carried out with advantage.

THE CHAIRMAN suggested that this question of distortion made it important to get away from the old types of steel and to use the newer ones. Most recognised steelmakers market a brand which had very little distortion, and the newer steels were more suitable for modern needs in this respect. He knew of two or three brands, at any rate for press tools, that were, as stated by the makers, very much better from the point of view of distortion, due to hardening, than the old carbon steels. That was true also of the oil-hardening steels generally. A good oil-hardening steel was generally much more suitable for press tools than water-hardening steel. It certainly would harden properly without cracking and without distortion.

On the motion of the Chairman, a hearty vote of thanks was accorded the author at the conclusion of the discussion.

THE

INSTITUTION OF PRODUCTION ENGINEERS.

A General Meeting of the Institution was held at the Engineers' Club, Coventry Street, W.1, on Wednesday, April 22nd, Mr. Butler (Vice-President) occupying the Chair.

The Minutes of the previous meeting were read and approved.

Mr. F. P. Turner, of Messrs. E. W. Bliss Co., Pocock Street, Blackfriars Road, S.E.1, then read a paper on "Press Tool Work," after which there was an interesting discussion in which several members and visitors took part.

PRESS TOOL WORK.

By Mr. F. P. TURNER, of Messrs. E. W. Bliss Company, Pocock Street, Blackfriars Road, S.E.1.

No class of machinery has helped more to develop our industries to their present high state of efficiency and rapidity of production than the stamping press and the special machinery used in the manufacture of all parts and articles made from sheet steel, brass, copper, zinc, tin plate, and other metals. The E. W. Bliss Company has the distinction of being the pioneer in this line of business.

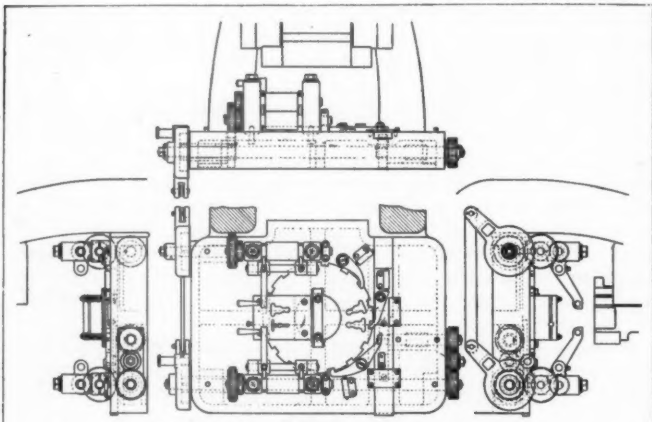
Commencing in 1867 the building of small pendulum foot presses and the making of plain blanking, perforating, and forming dies, they gradually began the building of presses operated by power, due to the demand for a higher rate of production and greater accuracy in the product. In a short time the use of power presses had become more general, the field for the use of these having become more widely extended by the development and designing of combination and other tools which permitted of rapidly transforming flat sheets into finished or partly finished shapes.

Progress in working sheet metal into commercial articles has been very rapid in recent years and has covered the stamping of not only the lighter gauge metals by the cold process but also sheet metals as heavy as half an inch thick and as large as the frame of an auto track or the end of a steel freight car, without heating the metal. In fact, from a very crude beginning in 1867 this art has been developed into a very elaborate science, so much so that the power press, with its many-sided applications, has to-day become recognised as an absolute necessity in plants where sheet metal is operated upon, and amongst other things it is directly responsible for making it possible to sell motor cars and other commodities at their present price.

In former years the machines used in working sheet metal were exceedingly simple, but the constant demand for cheaper and more uniform products has developed mechanical presses which now actually stamp many parts and even complete articles of light and heavy gauge which formerly had to be made from forgings and castings, such as side frames and cross-members, rear axle housings, front axles, engine pans, steering wheels, generator and starting motor frames, wheel hubs, wheels, brake drums, radi-

ator shells, etc., and particularly interesting are the presses and tools which have been developed for stamping and forming motor car bodies, fenders, cowls, radiator shells, etc.

In forming the above-mentioned shapes, it is necessary to hold the flat sheet under sufficient pressure to prevent it from wrinkling, and in the earlier days, when we had only single-action presses, it was necessary to apply enormous springs against the pressure plate to accomplish this. Experience showed, however, especially on large forming dies, that the spring-pressure device was not reliable and did not give uniform results, limiting the depth of draw and also stretching the metal. In the new type of presses used for the above-mentioned parts we eliminated the spring-



Combined roll and dial feed for Nº 21 press

Fig. 1.

pressure device and introduced the pressure plate, or, as it is more commonly called, the blankholder. By a simple arrangement of toggle links we are able to obtain a positive and uniform pressure, whether we draw 1in. or 20in. in depth. Besides this, the pressure against the crankshaft due to the resistance of the spring is eliminated, as the toggle links are operated directly from the main gears. In addition, you will note that, due to the toggle links being operated by both main gears, double safety is assured against the breaking of any of the toggle links or the stopping of the press, as the construction is such that either side of the driving parts is strong enough to operate the entire blankholder motion. This particular motion is controlled and covered by patents held by the E. W. Bliss Company. It will also be of interest to note

that mechanical presses have practically eliminated the hydraulic presses in forming side rails for motor cars.

About twelve years ago the first mechanical press was built to produce a right- and left-hand side rail for the Ford car. This press was built with a single-acting motion operating the slide carrying the die and forming the metal around the punch. The latest type of these presses has a double-acting motion, one for operating the punch, and one for operating the blankholder. The object of the blankholder is to clamp the blank securely against the punch so as to keep it flat whilst forming up the sides, this being very desirable, as it makes it easier to fit brackets, step hangers, and cross-members. One of these presses is turning out an average of 300 side rails every hour. At present, presses are built weighing more than 200 tons, to form side rails up to 21ft. long and 0·375in. thick.

The variation in the size of presses used in the motor car industry is naturally very considerable, considering that a motor car averages about 200 stampings and about the same number of forgings, most of which are made in forging presses, and this variation covers almost the whole list of presses from a bench press weighing about 250 lb., to a side-rail press weighing 600,000 lb. In the Ford plant the variety of presses used would fill a complete catalogue, showing one machine of each kind. One of the latest applications is the use of a multiple-spindle drill head on the slide of a crank press, the feeding being done by the descent of the slide when the clutch is tripped.

The pressed-steel car has developed some large and powerful presses, and it is possible to press the entire end of a freight car in one operation in a double-crank press of colossal proportions. Forging and extrusion of metal in power presses is still in the experimental stage, and new developments are being made every day.

Another interesting press development is going on in the drop forging line, especially in small, intricate forgings, such as levers, bell cranks, steering knuckles, small wheel hubs, gear blanks, etc. In the new process of forging these parts in power presses, the cost is cut down more than 50 per cent., and the products are better. We expect in a short time to see forgings weighing 2 lb. made from a 2-lb. slug and eliminating the flash altogether.

It is our purpose in this paper to describe briefly a few of the presses and tools which are used in the fabrication of most of the sheet-metal articles which pass through our hands every day. In regard to designation, presses may be properly classified by two methods: First, as to the work which they have been designed to perform, as punching, stamping, drawing, blanking, embossing, riveting, wiring, forming, broaching, trimming, and bending and forming presses. Second, as to their construction, as single-action,

double-action, triple-action, multiple crank, cam, knuckle-joint, toggle, or drop presses, etc. This latter method may be subdivided with regard to the frame, whether straight-sided, overhanging, upright, or inclinable, or whether made of one casting or built up in sections. Users generally designate presses by the first method, whilst builders employ the second.

We will begin by describing the simpler forms of presses, and will later refer to the more elaborate and entirely automatic machines. First, we have the standard type of inclinable power press; as its name implies, the body of this press may be used in

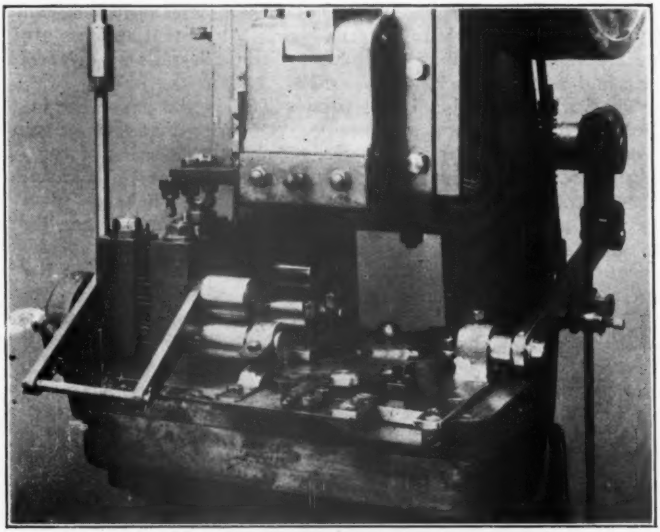


Fig. 2.—An interesting combined roll and dial feed.

an upright position, or can be easily set on an incline so as to allow the finished article to drop off the die by gravity. Presses of this type are built in many sizes, weighing from about 250 to 8,000 lb. They are often fitted with back gearing, and it is a type of press of which a very large number are used, perhaps more than any other type.

Next to the inclinable type is the press known to the trade as the Stiles power punching press. Many modifications have been made of this type of press by various manufacturers, but none has equalled the original machine in its important points of construction. The range of work covers a large number of operations

required in the manufacture of hardware, bicycles, locks, cutlery, tools, guns, sewing machines, etc. Nearly all the best manufacturing establishments in these lines, both in America and this country, employ them. They are made in various sizes weighing from 5,500 lb. to 12,000 lb., and with or without gearing.

Straight-sided power presses are used for the heavier kinds of stamping, shaping, trimming, punching, etc. They are built with or without gearing, and, if the nature of the work demands, with double or even triple gearing, and often of tie-rod construction. They are sometimes made with a side punch, adapting the press for trimming drop forgings. They are also made with an overhanging frame, an extra long stroke, and an increased die-space, adapting them for broaching, also for re-drawing and reducing the diameter of seamless copper and brass shells and tubes. Another type of straight-sided press is designed for operating sub-presses used in the manufacture of watches, clocks, jewellery, and other similar articles produced in large quantities and requiring great accuracy and uniformity. Presses of this character weigh from 1,500 to 185,000 lb.

While embossing may be done, to a certain extent, in almost any type of press, the heaviest work requires a special machine of a construction known as the knuckle-joint press; in this, heavy pressures are obtained by a comparatively low application of power. This result is obtained by the combination of a crank movement in connection with a knuckle joint, by which straightening of the knuckle joint great pressure is exerted, due to the enormous leverage obtained, and the elimination of the bending stress which is always present in direct-acting crank presses. The tie-rod form of construction is of particular advantage in presses of the knuckle-joint type, as a great saving of power is effected due to the fact that the tie-rods are shrunk in place, thus putting an initial compression on the side frames in excess of the pressure exerted by the press in action. This overcomes the stress incidental to a solid frame construction, which has to be made at each stroke of the press before the required pressure is obtained on the dies, with a resultant loss of power. This type of press is steadily gaining favour over the hydraulic press and the drop hammer, as its action is positive, and more uniformity in the work is secured at a greatly increased rate of production. These machines are made in several types by the various builders, but the construction preferred by the E. W. Bliss Company is to have the knuckle members and slide above the die bed. In this construction the weight of the slide on the up movement tends to separate the working surfaces of the knuckles and pins, thus allowing the heavy oil used for lubricating to be forced over the entire surfaces by means of a geared pressure pump. These presses are made to exert pressure from 200 to 2,000 tons.

The subject of multiple crank presses is a large one. In all probability there is no class of press in which development has been so rapid in the last few years as in the double-crank and multiple-crank types. Up to a few years ago, presses having more than two cranks and over four or five feet between housings were rarely built, while to-day presses having three or four cranks and from ten to twenty-one feet between housings are becoming common. With the increased number of cranks and width between housings has come the demand for more powerful presses, so that to-day this type of press is built with 15in. diameter of crankshaft, and in sizes which weigh 600,000 lb. Cast-steel machine-cut gearing is used throughout in machines of this description,

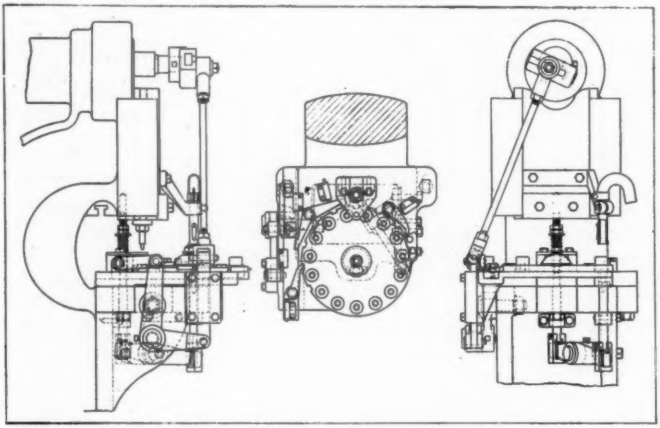


Fig. 3.—Dial feed and ejector mechanism.

and to avoid excessive torsional strain on the crankshaft it is twin-driven by mounting a driving gear at both ends. This type of press is driven by a powerful double-grip friction clutch mounted on the back shaft.

A modification of the multiple-crank press is particularly adapted for drawing and forming from heavy gauges of sheet metal articles of large area and considerable depth such as automobile radiators, mudguards, stove tops, bath tubs, and similar work. The construction is very rigid and of what is known as the tie-rod type, in which the bed, uprights, and crown pieces are tied together by four vertical steel tie-rods, which are shrunk in place and take the entire working stress, relieving all cast-iron members from tension. The design of the machine is such that power is transferred from the main driving gears to the outside

slide or blankholder through a series of toggles, so that a dwell of 110° is obtained. In order to maintain in presses, such as the one described, this simple and efficient construction, and at the same time avoid excessive torsional strain, it will be noted that power is transferred to the outside slide or blankholder from both ends of the press. This construction is also followed out in connection with the crankshaft which operates the inner slide, in that the crankshaft is twin driven, a driving gear being mounted on both ends of the shaft. Further to obtain minimum wear, all connection pins are hardened and ground. The control of these machines is by means of a powerful hand-actuated friction clutch of the double-grip type, through which the operator at all times has under control the moving parts. Both flywheel and tight pulley are arranged with safety couplings as a precaution against

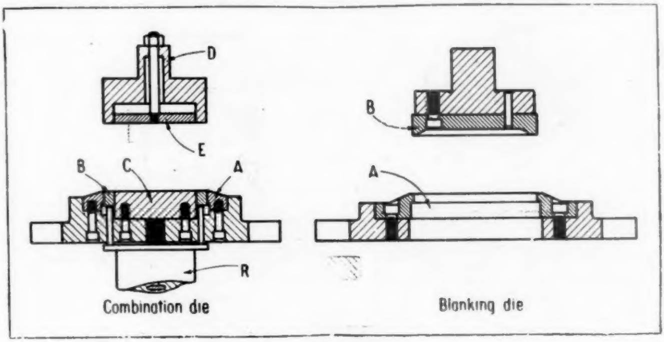


Fig. 4.

possible damage to the machine through dies being incorrectly set, or any foreign article being placed where it would interfere with the proper operation of the machine.

Double-acting presses, i.e., presses with two slides, the outer for cutting and clamping the blank, and the inner for drawing the cup or shell, are of the three-crank cam and toggle types. These presses are made in a variety of styles and sizes. The three-crank type is the best adapted for the cupping of shallow work or when the stock is of heavy gauge (as the blankholder has no period of dwell). This type of press permits of great speed, due to the absence of cams, and is largely used in the manufacture of cartridges for rifles and small arms. These presses, fitted with gang cupping tools, can produce as many as 2,000 cups per minute.

The cam type of double-action press is best adapted for work

upon light gauge stock and where the blank must be held for a period to prevent wrinkling of the edge of the cup. These presses are used largely in ammunition factories for the production of shot shell heads and bullet jackets.

The requirements of armature work for electrical motors and dynamos have led to the construction of presses which differ in many essential points from those used for other classes of sheet-metal work, though modifications of double-crank presses are extensively employed in this line of manufacture. Such presses are designed for simultaneously cutting the inside and outside of plain rings, with or without key notches, or for cutting complete discs or segments. The presses are supplied with automatic knock-out attachments for removing the cut blanks from the die and punch, and are made in a number of sizes. Rings, discs,

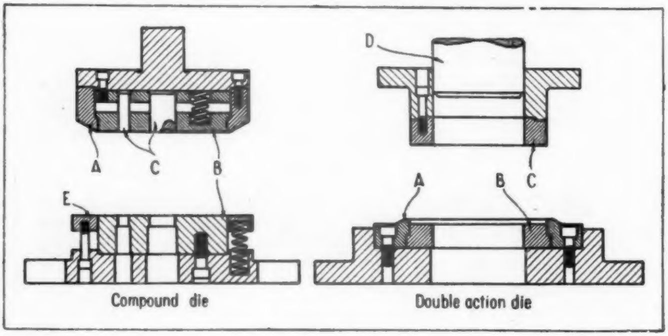


Fig. 5.

or segments, as they come from these presses, require to be notched, and this operation is performed by a special automatic machine. This machine is provided with a rotating table which is indexed by means of change gearing or by master disc with ratchet movement. The disc to be notched is placed on the rotating table, the treadle is depressed, and the disc is automatically revolved until the complete number of notches has been cut, one or more notches being cut at each stroke of the press. After the disc has made a complete revolution, the action of the machine is automatically stopped. Presses of this kind are capable of notching discs from three to sixty inches in diameter, and are also furnished with automatic attachments for notching segments for discs of any desired diameter.

Automatic feeds in connection with power presses are of numerous types, but those most frequently employed are the simple

and double roll feed, the dial feed, the gravity feed, push feed, reciprocating feed, disc feed, or a combination of two or more of these types. The subject of these automatic feeds and the various kinds of work for which each type is adapted is a very interesting one, but time will not permit us to do more than just touch on a few of the most common types.

The double roll feed is for taking the strip stock, usually in coils, and carrying it through the guides to the dies to be operated on. It is used in the manufacture of an endless variety of articles, as bicycle chain links, buckles, locks, keys, trunk trimmings, etc. The single roll feed is substantially the same, only it does not have the second pair of rolls which are used to keep a proper tension on the stock, and also for carrying away the scrap. An interesting combined roll and dial feed is shown in figs. 1 and 2.

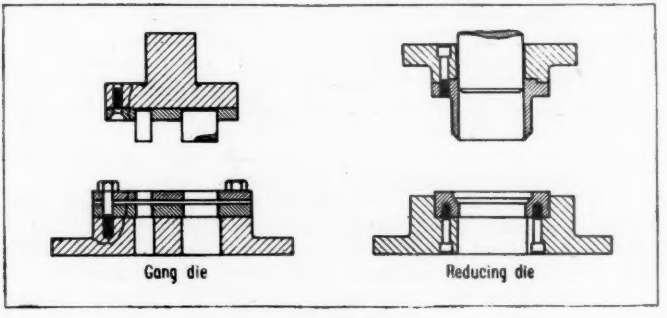


Fig. 6.

Combined Roll and Dial Feed.

The mechanism is operated from the end of the crankshaft by means of an adjustable crank end and rod. The same spindle which operates the rolls is carried through under the bolster and actuates the dial feed slide by means of a rack and pinion. Change gears can be supplied to alter the stroke of the slide if necessary.

The stock is fed from the front of the machine in the form of strip, and is conveyed by means of the front rolls to a follow tool. Two operations are then performed, in the last of which the article is blanked out and falls through into a space formed for its reception in the dial plate. The scrap stock continues and is taken away by means of the near pair of rolls. The dial plate transfers the blanked article to the opposite side of the machine, where another operation is performed on it, the finished piece then

falling through a hole in the bolster into a suitably placed receptacle.

Another type of mechanism is a combined roll and station dial feed which achieves the same object as that shown in the illustration, but is adapted to the press in a different manner. The rolls are driven by the crankshaft from an adjustable crank end to a ratchet; part of the connecting rod can be seen. The slide receives its motion through a system of levers from an eccentric on the crankshaft. The strip stock is fed through the rolls from the front of the press, the sequence of operations being identical with those previously described. A handle at the front of the bolster is used to release the rolls in order that the stock can be inserted between them.

Dial feeds are adapted for the second, third, and fourth operations on articles previously cut and partly formed. The articles to be operated upon are placed in the pockets of the dial, and as the punch descends the dial is revolved automatically, stopping just before the punch enters the pocket. After the article has been operated upon, it is automatically thrown out of the dial, leaving the pocket ready for another cup or blank. In shell reducing operations the shell which is operated on is carried through the die and is stripped from the punch as this is drawn out of the die on the up stroke of the press.

Fig. 3 illustrates a dial feed fitted to a No. 3 " Stiles " press The movement of the slide emanates from the crankshaft, and is transmitted through a series of levers which can be seen at the left hand side of the picture. The end of the shaft carries an adjustable crank end, by means of which the feed of the slide can be adjusted to a nicety. The work to be operated upon is placed in the dial plate by the operator. The article is then carried round in the dial to the punch, where the necessary operation is performed upon it. The sample is stripped from the punch by the stripper, which is shown, and falls back into the space in the dial. The press is further provided with a special ejecting device underneath the bed, whilst the ejector consists of a rocking lever actuated by the ram as it descends. This lever moves a vertical rod up through a hole in the bolster and into one of the holes in the dial, which has fed round into this position. The stamping is thereby lifted out of the dial plate and enters a tube. It will be understood that the ram, when descending, actuates the ejecting device and simultaneously brings the tube down over the hole in the dial ready to receive the article when it is lifted out by the ejecting rod. The sample is prevented from falling back into the dial by means of a spring latch in the side of the tube. The arrangement of the mechanism will be seen from fig. 3

A typical set of five operation discs is shown in fig. 7. In the case under consideration the article is first produced in a

double-action die working in a cam-drawing press, producing the cup shown. This, an electric lamp fitting, is now transferred to the five operation press, where it passes through a series of dies. In the first three the stamping undergoes simple forming operations, the nature of which is plainly shown. The fourth operation consists of punching a hole in the top of the dome. The scrap is left in the top tool, whence it is eventually ejected, by subsequent punchings, through a hole in the side of the tool. The fifth and last stage forms two indents in the side of the pressing. The transportation from die to die is effected by means of feed bars, the operator only having to place the cups on a revolving table at the side of the machine.

In fig. 8 is shown a die in which several operations are performed without the interference of the operator. The first stage

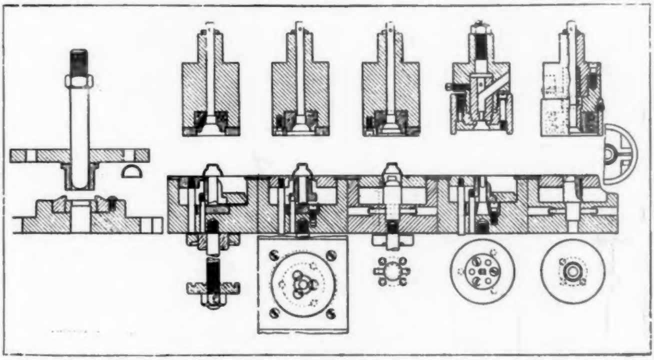


Fig. 7.

consists of a blanking tool in which the article is cut out of the strip stock. The blank then falls through on to feed bars, which are in position to receive it and which feed it to the next operation, where partial forming takes place. In the third operation, the partially formed pressing is fed forward again, where it is bent to shape round the mandrel. The same mechanism which actuates the feed bars causes the mandrel to recede, thus shedding the article, which falls away through a hole cut in the bolster. The manner in which the feed bars receive their motion is partly shown, the two side bars receiving a reciprocating motion by means of a cam and levers from the crankshaft.

Gravity feeds are largely used for shaping, trimming, or lettering fruit jar tops, or for perforating, lettering, embossing, or shaping shells of brass, tin, zinc, steel, etc. All that is required

of the operator is to keep the inclined chute full of the articles to be operated on. These articles are allowed to drop automatically, one by one, by gravity, under the punch, and after the operation they are discharged by gravity. Sometimes the article to be manufactured requires a series of operations. Articles of this nature are oil can tops, screw tops, burner shells, stove door knobs, lantern parts, or similar articles made in large quantities. A combined feed is the best to adopt in this case. It is better that the first operation or shell be made in a combination or drawing die. The work is then placed on a friction dial feed from which it is automatically carried by a lateral feed device from one to another of the various dies. These presses can be made

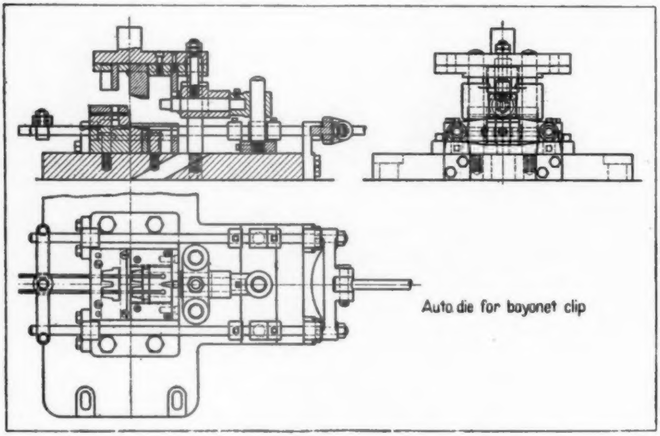


Fig. 8.

with four, five, six, or more die slides if the nature of the work demands it. Sometimes, in place of a friction dial feed, a positive dial feed is used in connection with the lateral feed. Then, again, a single roll feed is employed for feeding stock from a coil, and after the first operation the article is carried in the lateral feeding device previously described. The capacity of a press of this kind is equivalent to that of from ten to fifteen hand-fed presses.

Foot and screw power presses are used by manufacturers who do not have power in their factories, and may be employed for a variety of cutting, stamping, lettering, and forming in the manufacture of sheet metal goods, also for jewellers' use. They are made in many sizes, weighing from 50 to 3,000 lb.

The Flat Edge Trimmer.

In practically all cases stampings or drawn shells produced by the ordinary power press have to be put through additional trimming operations to remove the flash, or scrap, before they can be used. This process has been more or less unsatisfactory and has caused much trouble in many cases, particularly where it is necessary to have the edges of the finished stamping in a true plane. In work where it is necessary to join two or more of these pressed metal parts by welding or soldering, or similar operations, it has been customary to follow the trimming operation by filing or grinding operations to produce the flat surface necessary. A fillet of any size at the point where the scrap is trimmed has, of course, been a decided disadvantage, and it has been the general custom to use dies with edges as sharp as possible in order to avoid this, and these edges have introduced difficulties in the drawing or stamping, causing a considerable loss from breakage of the material. Another disadvantage has been that in the working of precious metals considerable valuable material has been lost in the filing and grinding operations. With a view to overcoming these disadvantages and troubles, the E. W. Bliss Company has recently developed a machine to be known as a flat edge trimmer. It is adapted to trimming the flash or scrap from articles when the line of juncture between the scrap and the drawn body is in a single plane, so that a flat surface is produced when the article is trimmed. The work as delivered from the machine is in condition for uniting by soldering or welding and requires no further treatment before either of these operations is performed, the flat surfaces on the edges of the material being approximately the same width as the original thickness of the metal. During the trimming operation, the stamping is held in a female die and supported on a pad to regulate the trimmed depth. The upper die is carried on the slide, and the cutting edge is formed to enter the stamping freely, but the edge is shrouded to prevent it going below the cutting edge of the lower or holding die. On the face of the upper die a floating filler piece is secured, the function of which is to hold the stamping firmly against the pad in the lower die. After a stamping has been put in place in the lower die, the clutch is tripped and the slide, holding the upper die, descends; the filler piece entering the stamping and forcing it to its proper position in the lower die, and the cutting edges of the dies are in the same plane. During a dwell of the upper die slide, the lower die is given a side-to-side and front-to-back movement, sufficient to cut away the scrap with a direct shearing action, leaving the edges of the stamping in a true plane and of a width of edge equal to the original thickness of the stock. As the merits of this process become better known

the demand for machines of capacity to trim large and heavy stampings is anticipated.

So far we have confined ourselves to the question of presses, now we come to the tools used in these machines. Dies are now used so extensively and have made possible such wonderful

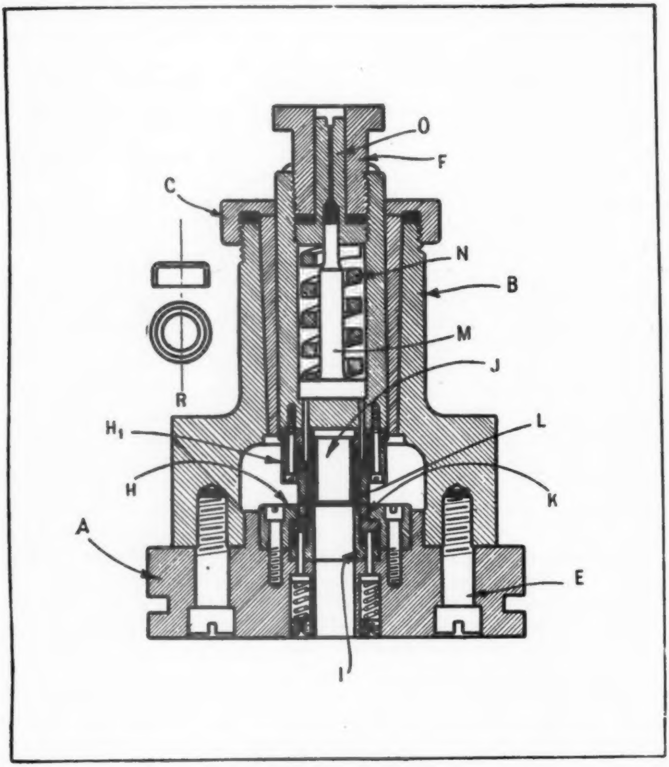


Fig. 9.—Typical sub-press tools.

results in the rapid production of sheet-metal parts, that die design and construction has become a subject of great importance to everyone interested in modern manufacturing methods. There is probably a greater difference in the methods employed in die making than in any other branch of tool or machine manufacture, because of the endless variety of dies, which has often made it

necessary for die makers to devise their own methods of manufacture.

With regard to cost, generally speaking the cost of well-made press tools is small, but where elaborate tools are necessary, the initial cost is quite likely to be heavy, but this is of little moment where large quantities of a particular article are required, and the advantages of this method of production far outweigh the first cost of the tools.

Blanking Dies.

The most common type of press tool is the blanking die. These dies are used, as most of you know, for blanking pieces of a particular shape out of sheet metal, the shape of the die being dependent, of course, upon the shape of the particular blank required. If the piece is small and fairly regular in shape the die may be made from a solid piece of steel, but if it is large or irregular it is generally built up. If the metal to be blanked is thin and comparatively soft, the cutting edge is sometimes welded to the iron base. This could only be done if the cutting edge is made of comparatively soft steel. Welding is not resorted to when the stock is hard and the cutting edge is made from harder steel.

In fig. 4, A is the bottom tool steel, B is the top tool steel. These steels are housed in cast-iron holders, the amount of steel and cast-iron depending upon the work to be performed. In some cases the top tool or punch steel is left soft to enable it to be hammered up when worn. If thick or hard material is to be blanked, the ring B should always be hardened.

Blanking dies are often sheared to relieve the blow on the press. If the blank is required "flat," shear is put on the bottom ring A, but if the punching is scrap and the stock must be kept flat, shear is put on the top ring or punch. The amount of shear permissible depends upon the thickness and kind of material to be blanked. This clearance between the punch and the die depends, of course, upon the material to be punched. If a blank of given size is required, the bottom die is made to size and clearance is allowed on the punch, but when holes of a given size are required the punch is made to size and the clearance is allowed on the ring or cutting edge.

Blanking dies are often worked without lubricant, but it is generally better for all blanking dies to be lubricated. Lard or sperm oil can be used when punching steel, iron, brass, or copper, and kerosene is the best lubricant for aluminium.

Compound Dies.

Fig. 5 shows a compound die in which A is the cutting ring, B is the punch, in this case in the bottom of the tool, the punches

C are for the small holes, D is the shedder in the top tool, and E is the spring ring for stripping the stock. Many dies are made on these lines, and small armature discs are often blanked in this type of die. These dies should be fitted with columns or pillars. This makes the die easy to set, and if the columns are sufficiently large, independent of the press. The press should then only be

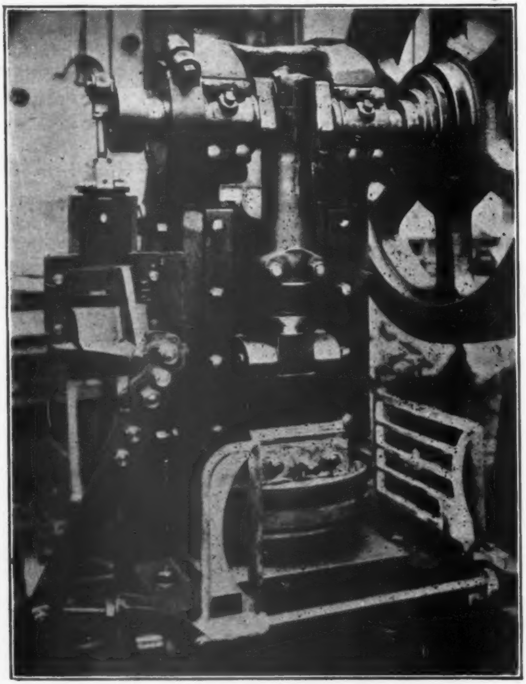


Fig. 10.—The Broughton-Positive press guard with side gate.

used for supplying the power, the columns looking after the alignment of the tools; consequently the top tool should not be rigidly fixed to the ram of the press in a lateral direction. This is practically the sub-press principle, but pure sub-press dies, which we shall discuss later, are, generally speaking, very elaborate and costly, and would only be used in the case of very small work where great accuracy is essential.

Combination Dies.

These dies are used for cutting and drawing shallow articles in one operation. In fig. 4, A is the cutting edge, B is the pressure ring, C the centre or forming block, D is the top tool or punch, and E is the pad or ejector. A rubber buffer, R, is for maintaining pressure between B and D, and keeping wrinkles out of the article. The stock is fed over the die, and the punch descends cutting the stock as shown. The punch continues to descend and forms metal over the centre block. When this operation is completed the top tool returns, the ring E strips the article off C, and the spring pad sheds the piece from the top tool. This method leaves the formed article on the face of the die; to avoid this the ring E, instead of being operated by a spring, is sometimes forced down, when the top tool is almost at the top of its stroke, by what is termed a positive knock-out. If the press is inclined the piece will fall clear when forced out, without becoming entangled with the stock.

Combination dies are generally used for producing, round, oval, and rectangular articles in tin-plate or from thin steel or brass.

Three-quarters of an inch is considered to be about the maximum depth that can be drawn in this type of die, but with only a small corner radius on block C it may be impossible to draw three-quarters of an inch. Articles of 1in. deep can be sometimes produced, but the percentage of scrap is apt to be high; this is on account of excessive pressure between the faces of B and D, due to too much compression on the rubber buffer R. Various devices for relieving or compensating for this excessive pressure are in use, but generally speaking they have not been found very satisfactory.

If articles of greater depth are required they are produced in double-action dies, either in one or more operations, depending upon the depth required.

Double-action Dies.

In fig. 5, A is the cutting ring, B is the drawing ring, C is the blank holder ring, and D is the plunger. The press in which these dies are operated has two actions: first, the blank holder descends, cuts the blank, and continuing on holds the blank between the faces of B and C. The blank holder now dwells and the plunger descends, forming the article in the forming ring B. If the article formed has a sharp edge it can be pushed through the ring and off the punch, but if it has a flange it is returned, by a riser operated by the press, to the face of the die.

Double-action dies can be made to cut and form, or simply to form a blank which has been previously blanked, or cut in rotary or other shears. The depth that an article can be drawn in a

double-action die depends on the quality and kind of material. For good quality brass and aluminium it is generally possible to draw an article with depth equal to diameter. In the case of mild steel, a depth equal to two-thirds the diameter is considered good practice. If the article has a flange at the top these depths must be modified.

When the die is being set, the pressure on the blank between the faces of C and B must not be too great, but just enough to

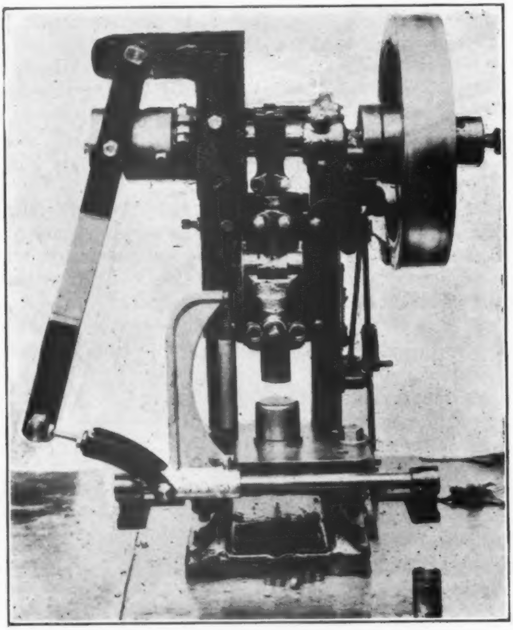


Fig. 11.—A cam-operated guard for light presses.

prevent wrinkles from forming, and at the same time not enough to cause the plunger to push the bottom out of the shell.

When the shell is being drawn the metal at the outer edge tends to thicken up, it is therefore necessary to allow ample clearance between the plunger and the drawing ring, otherwise there will be a tendency to iron the metal. This in itself would be an advantage, and would tend to keep the thickness of the metal constant, but too much resistance due to ironing would probably cause the

shell to fracture. The diameter of the drawing punch is generally made about three thicknesses of material less than the diameter of the drawing ring. When drawing rectangular shells the corner radius should be as large as possible, the smaller the radius the shallower will be the maximum draw. It is considered possible to draw a depth equal to five or six times the corner radius, though this is not a hard-and-fast rule, and depends to a great extent on the other dimensions of the article.

If deep shells are to be drawn it is necessary to use one or more reducing operations, the amount that can be reduced depending to some extent on the thickness and quality of the material. A reduction in diameter of, say, 25 per cent. could quite possibly be effected in stock up to, say, $\frac{1}{8}$in. thick. The amount of reduction would also depend upon the amount of ironing done.

A shell could be annealed after the first drawing operation and frequently during the reducing process; at least, after every two operations.

If the draw is at all great, the top of the shell will be very irregular and a trimming operation will be necessary. When reducing dies are used for reducing or sizing long shells, they are sometimes actuated in rack driven presses. These presses are used to ensure an even drawing speed, which is not possible with crank-driven presses.

Lubricants for drawing are most necessary. For brass or copper, oil or soapsuds can be used. For steel, lard oil, or tallow (sometimes containing graphite); and for aluminium, vaseline or lard oil. Tin-plate can be worked without lubricant, but oil of some sort or other is an advantage. Other types of tools are shown in fig. 6.

The Sub-press.

A sub-press cannot be defined as a special class of die, but merely as a principle on which different kinds of dies may be operated. The sub-press consists in having the upper and lower dies combined into a self-contained unit, so arranged as always to hold both members in exact alignment with each other. The compound die is most used in sub-press work, as it ensures a high degree of accuracy in the work produced, as all pierced holes bear a fixed relation to the outside contour of the blank, thus making variations in the feeding of the stock a negligible quantity. In some cases the sub-press may be adapted to take several sets of dies, but it is advisable to have a separate sub-press for each set, one advantage of which arrangement is the rapidity with which tools may be changed by simply loosening the clamps, changing the sub-press, and re-clamping. In addition to this, there is no time wasted in aligning the punches and dies, and the danger of shearing the punch or die is entirely eliminated. The

difference in cost is more noticeable in a simple low-priced die than in a compound die; in fact, in the latter case it often occurs that a complicated die can be made with less expense by using a sub-press than by any other method.

The die shown in fig. 9 was designed to blank and form up a copper cup or capsule used in the manufacture of balance wheels

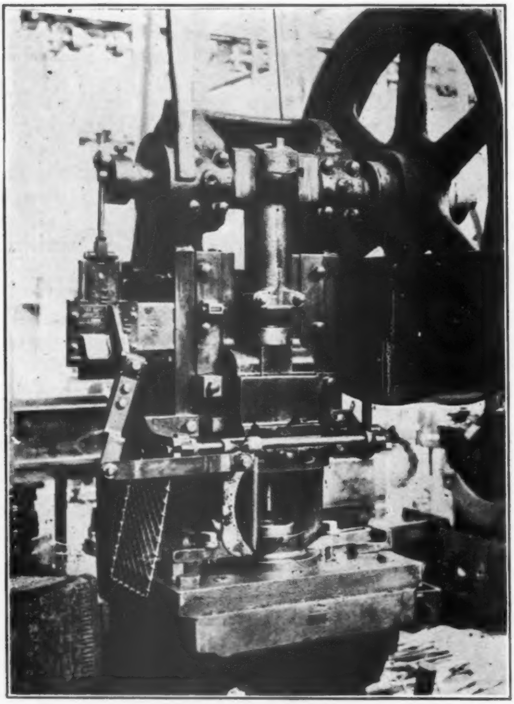


Fig. 12.—An alternative arrangement of the "Broughton" press guard.

for watches. The copper strip is fed into the press, which then blanks out and draws the metal into the shape shown at R, at the same time punching the centre hole. A is the base of the sub-press, B the body, C the cap, and D the plunger, all these being of cast-iron machined to size. The body and base are held together by two screws, E, in the usual manner; F is the buffer plug which receives the thrust of the press piston; G is the

babbitt lining of the body B; the outside diameter die and the outside diameter punch are shown at H; J is the die for cutting out the centre hole, and K is the punch for this hole. The parts H and J also serve as forming dies in bringing the metal to the proper shape. The "shedders" or strippers L and M are supported by four push-pins, those of the former resting upon springs, the tension of which is controlled by short threaded plugs, and those for the latter abutting against the piston N, which is

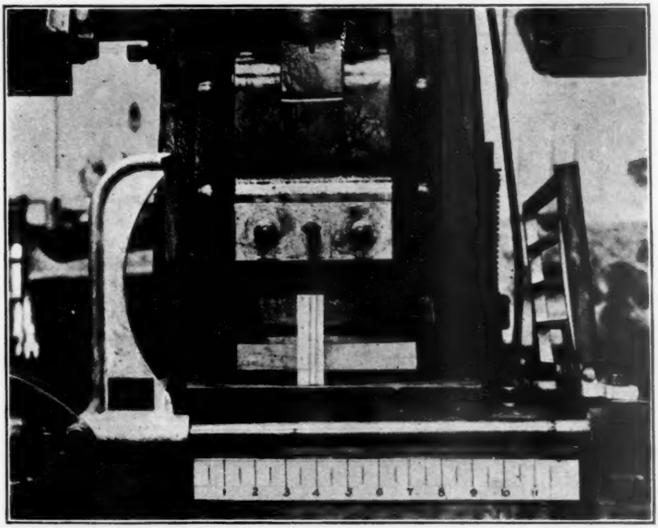


Fig. 13.—The "Security" automatic press guard at the commencement of its stroke.

pressed down by the large spring O, the tension of which is controlled by the plug P.

The operation of the die is as follows: the press ram being at the top of the stroke, the copper strip is fed in across the top of H, and as the ram descends, the blank is cut from the strip by the punch and drawn to a cup shape between the inside edge of H and the outside edge of J. Simultaneously, the centre hole is punched by K and J. As will be seen, the punch K is made a trifle short, so that the drawing operation will have begun before this hole is punched; this prevents any distortion of the piece by the punch K.

A little trouble was experienced with this tool at first, on

account of the air in the hollow plunger D forming a cushion when it was compressed by the rising of the piston M, thus preventing the proper working of the die. This was finally obviated by making a small groove at the side of the piston where it worked in the plug O, and drilling a vent hole as shown. This allowed free communication to the atmosphere, and from then on the die gave complete satisfaction. The variation in size among the cups, or capsules as they are called, is never more than 0·001in., either in diameter or length.

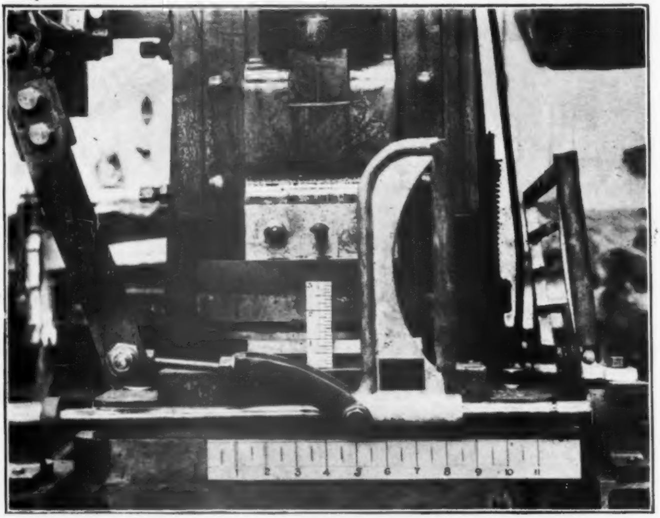


Fig. 14.—The guard closed, showing the relative movements of ram and guard.

Our paper would not be complete without some reference to the safety devices for guarding the operators' fingers, which have been placed on the market within the past few years. These have been many and various, but out of some fifteen or sixteen types only two or three have survived the test of general working conditions. Of these, we consider that the Broughton-Positive power press guard is the best and most closely approximates to a genuine "fool-proof" safety device.

This guard, as many of you know who are users of it, operates from the exposed end of the crankshaft of the press. To the end of the crankshaft is keyed or pinned a collar, bored to the correct

size of the shaft, and to this collar is attached the driving pin, set slightly over dead centre. This carries a gun-metal bush, to which is attached a connecting rod, which in turn is attached to the slide plate of the action. A cam slot is formed in the slide plate in which a pin and roller works, which in turn operates the driving shaft the moment the press commences to work. This motion is transmitted to a shutter through a link and lever arm, causing it to be thrown across the work space as the ram descends. In order to provide any sort of safety it is, of course, necessary that the motion imparted to the shutter should be quicker than the motion of the press, and the illustrations figs. 10 to 14 show the relationship between the movements of the ram and the shutter. We have fitted a great number of these guards in the London district, and we are constantly being told of cases where they have prevented very serious accidents. One firm with a large battery of all kinds of presses was constantly having accidents, and fitted these guards over twelve months ago. Their press shop foreman told me a few days ago that they had not had an accident since; on the other hand, he had himself seen several cases where the guard had operated and prevented serious accidents. The fact that there are over 6,000 of these guards in operation to-day proves that power press users are taking a very humanitarian view of their position as employers of labour, and that there are very few of them who would care about any of their employees going about for the rest of their lives minus their fingers for the sake of saving the price of an efficient safeguard on one of the most dangerous machines there is.

THE

INSTITUTION OF PRODUCTION ENGINEERS.

A GENERAL Meeting of the Institution was held at the Engineers' Club, Coventry Street, W.1, on Wednesday, May 20th, at 7.30 p.m.

The Chairman introduced Mr. S. C. Downes, of the Accounting & Tabulating Corporation of Great Britain, Ltd., who read a paper on "The Mechanical Compilation of Costs." This was followed by an interesting discussion.

THE MECHANICAL COMPILATION OF COSTS.

By Mr. S. C. DOWNES, of the Accounting and Tabulating Corporation of Great Britain.

Before we investigate the application of machines to any specific branch of costing, we must examine the underlying principles on which they have been evolved. The development of the machines has not been haphazard, but has been based on two main principles.

(A) That all figure work in accountancy, costing, or stores control consists of grouping together or placing in consecutive order items of labour, material and expense, and totalling them to produce the abstracts of accounts or statistics.

(B) That to do this effectively the items must be entered separately in the first instance so as to achieve a maximum mobility. If, now, this mobility can be combined with mechanical handling to reduce clerical error and fatigue, we are on the high road to maximum efficiency. The item entries have hitherto been hand-written or typed, and do not lend themselves to any process of mechanical handling. In the Powers system the items are made concrete by punching the date into cards, which become permanent mechanical carriers of the facts to be handled.

Therein lies the main advantage of the system, in that the machines have been designed to sort the cards into any group or sequence and to print out and add up at will all the items to obtain the results aimed at. Thus maximum mobility is assured, and the attainment of accuracy and speed is obtained by the use of untiring mechanism.

Because of this feature it frequently follows that in the particular application of these machines to individual requirements, it becomes advisable to abandon the approximations and short cuts that have been developed under the previous manual methods.

May I at this stage, therefore, emphasise a warning that it is necessary to give to all those who are unfamiliar or only partially familiar with the application of the perforated card system? In all cases under review, the problems should be reduced to their elementals irrespective of the complex methods that have arisen as a result of previous limitations.

As there are three main functions to be performed, the machines

naturally fall into the same divisions, namely, punches, sorters, and printing tabulators. These will be described in detail.

Punches.

The function of a punch is to pierce the card in the correct position, both vertically and horizontally. Certain requisite features are necessary to obtain accurate and rapid working. These are :—

(*a*) The operation must be simple to enable unskilled labour to be employed thereon.

(*b*) Undue exertion must be eliminated, i.e., the machine should do the work.

(*c*) Provision must be made for gang punching, or, in other words, for retaining a setting in any field where information common to a group of cards occurs.

(*d*) For checking purposes the first card punched must be kept on the top of the pack.

(*e*) Higher production is obtained through mechanical feed and ejection of cards.

(*f*) Skipping of unused columns must be possible.

(*g*) Setting must be a one-handed operation, leaving the other free to turn over the data sheets.

(*h*) The stroke of keys (if used) must be light, so that complete piercing of the card or setting of the punch is assured.

(*i*) In some cases visibility of the card whilst setting must be certain.

(*j*) Printing of the information on the card as well as punching is necessary on some work.

The Powers system provides three types of punching machine, so that every variation of work is amply provided for; other machines are being developed to suit requirements as they present themselves.

The Automatic Key Punch.

The automatic and visible key punches are those in most frequent use, one of these being shown in fig. 1. For brevity it is called the A.K.P.

Cards are put into the magazine in the front of the machine and are ejected at the back, the front magazine holding fully one hour's punching and the back about twice that quantity. The cards are mechanically fed to the punch plate by a picker knife through a throat, thus ensuring that only one card shall pass it at a time. The cards are turned over in the eject box, this fulfilling the requirement mentioned above.

The carriage consists of a row of twelve plungers corresponding to the number of holes in a column; these plungers are actuated

through Bowden wires by the keys on the right-hand side of the machine. At each stroke of the key the carriage moves one column to the right, as does a typewriter carriage; provision is also made for skipping any column or columns by positioning the small plates in a comb to the correct position, and a scale having the column number is traversed by a pointer to show on which column the carriage is positioned. The heading of a printed card may be slipped behind this scale to show the field rulings. The carriage is returned by means of the lever, during which movement the previous setting is wiped out. Provision is also made to move the carriage without unsetting if necessary.

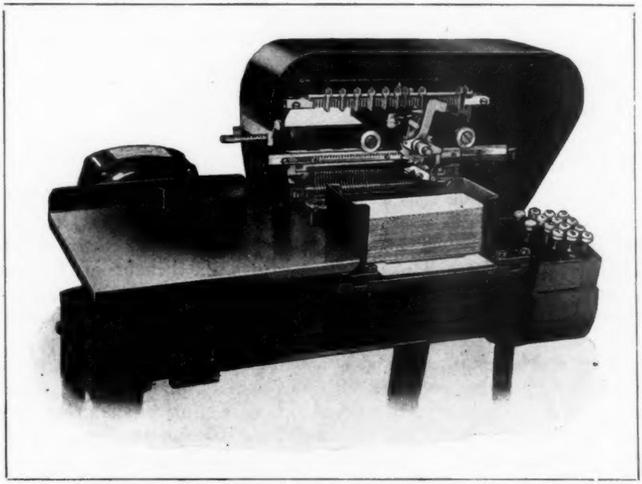


Fig. 1.—The automatic key punch.

Power is provided by a $\frac{1}{8}$ h.p. electric motor, the clutch key being depressed to produce the actual power stroke. For continuous punching of similar cards, the clutch key is kept down until the required number of cards have passed through the machine.

For gang punching, a margin stop may be set to prevent the carriage being restored as far as columns one to fifteen, but beyond this the restoring levers may be positioned to prevent restoring on any or all of the 45 columns. These have a very useful action, because to change the gang punching setting the new information has only to be put in by means of the keys in the usual way, when the old setting is automatically unset, the field in question

can be skipped or reset as desired. Incorrect setting may be easily rectified by returning the carriage with the knob and re-setting with the correct key, because the card is not punched until the clutch key has been depressed. The touch required on the rubber key tops is lighter than that of a typewriter, so that physical fatigue is almost eliminated.

From this description it will be seen that the above list of requisite features is very fully covered by the design of the machine, with the exception of (*i*) and (*j*).

The visible key punch, symbol V.K.P., is particularly designed to give absolute visibility of the card during setting for cases where the information to be punched is written on the card itself. The machine is similar in working to the A.K.P., but a polished plate with guides is provided instead of the magazine on which the operator places the card to be punched. On depression of the clutch key the card is automatically fed into the machine and punched.

The Printing Punch.

The printing punch is a later development designed for use in circumstances where a complete visible record is desired, as, for instance, a Powers store record, in which the card itself would form a stock list. This machine brings the benefit of Powers methods within the scope of the small business, the client purchasing a punch and having his sorting and tabulation done in the Powers service department.

The special feature of this machine is the combination of a hand-fed punching machine with full spacing and skipping functions, and the addition of a typewriting section which prints the information along the top edge of the card simultaneously with the punching stroke. Much of the future development will be along lines of decentralisation of punching; that is, making the Powers card the original entry and utilising the storekeeper, the cash-till girl, or the station booking clerk, who usually have idle moments but whose attendance must of necessity be continuous.

For such a purpose this machine has been designed. Before leaving the punching operation, a word might be said about the time required to punch cards. The production, of course, depends very largely on the form in which the matter to be recorded is presented to the operator and the number of columns being punched in each card. Thus with typed copy such as is easily read and a full card, speeds of 300 an hour can be continuously attained. If the data has to be searched for, the speed will be reduced, and if gang punching or empty fields occur it may be greatly increased. In estimating cost of punching, 300 an hour is taken, as it is a very safe figure to work upon.

The Sorter.

After punching, it is necessary to place the cards in the order required for tabulation. For instance, in the example illustrated, the value of goods sold by each traveller in consecutive order numbers will be one requirement, and totals will have to be taken after each traveller. In a machine to do this we may again compile a list of desirable features.

(*a*) Rapidity of functioning.
(*b*) Simplicity of operation.
(*c*) Accuracy and reliability.

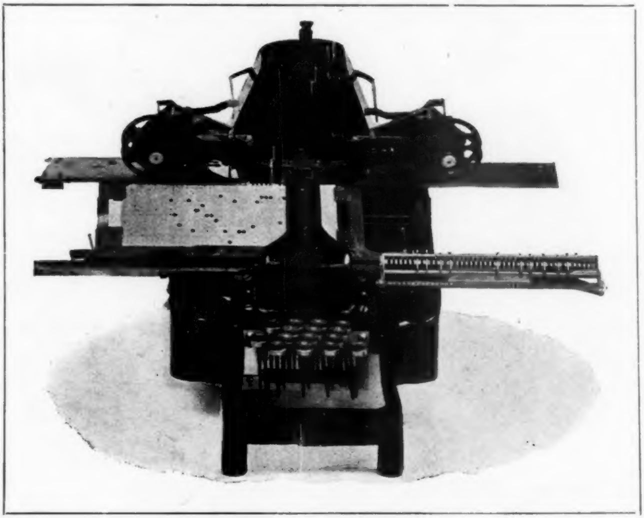


Fig. 2.—The printing punch.

(*d*) In some cases the counting of the cards.
(*e*) Automatic functioning.
(*f*) The machine must stop when all cards in the magazine are sorted.
(*g*) Cards not punched must be thrown out, i.e., space and total cards.
(*h*) Sorting must be possible on any column from 1 to 45.
(*j*) Rapidity of setting on any field.
(*k*) It must be possible to prevent any particular hole or holes functioning.
(*l*) Easy withdrawal of cards from the pockets.

The Powers sorter shown is driven by means of a $\frac{1}{8}$ h.p. electric motor, and contains a knife and throat feed, as in the case of the A.K.P. The cards then pass between two perforated plates, and are arrested in position momentarily by means of a card stop. A carriage carrying a pin box of twelve pins then descends upon the card, the pins being held against the card by lightly controlled pressure. Under one of these pins there will be a hole in the card, allowing that pin to pass through the card as the carriage descends, all the other pins in the pin box being

Fig. 3.—The sorting machine.

lifted by the card. Lying along the twelve pins is a lock plate which is hinged about an axis parallel with a line going through the points of the pins, but in a higher plane. The top portion of this plate is kept against the rounded shoulders of the pins by spring pressure, and with the pins at their lowest position lies over the shoulders. When the eleven pins rise on the card, the top edge is thrown out by means of the shoulders, and the lower edge is pushed into a step cut in the lower part of that pin which still remains in the lowest position, having nothing to lift it due to its passing through the hole; this one pin is thus positively

locked and is driven still farther by the descent of the carriage. Under the lower perforated plate is a second carriage containing twelve pin nipples on the ends of Bowden wires, each corresponding to one pin, and each connected through the Bowden wires to a cam setting plunger for the box into which the card has to fall. The plunger sets a cam which opens the lid of the corresponding box at the correct time for the card to pass in. The cam is then tripped, and the box lid shuts, until another card punched in the same hole is fed to the machine. The cards are carried the length of the machine by a row of wheels and rollers, whose centre distance is just less than the width of the card; thus one pair gets a good pull on the card before the last has finished pushing it.

Although it has taken some time to describe the action, the mechanism is simple and strong, all the work being accomplished by sound mechanical movements, so that failure to operate is reduced as near to the vanishing point as can be guaranteed in any machinery.

To move from one column to another, the operator releases the lock and depresses the knob as far as it will go, then the carriage is free to slide to any desired position. On releasing the knob, it rises and locates the carriage by a key entering one slot in the bar; the lock is then pushed in to prevent any possibility of kinetic energy moving the knob even should the spring break. It is impossible to unlock the carriage unless it is at its full height, thus preventing the operator from attempting to move it whilst the pins are projecting through the perforated plates.

The cards are placed in the magazine, and a lever switches on the motor. After the last card is fed from the perforated plates a plunger drops and switches off the power, thus advertising the fact that the machine requires more cards.

There are thirteen boxes, the end one of which is permanently set open; then if there should be any cards in the pack which are not punched in the column being sorted, they will pass through the machine into this box and may be removed. As it is customary to sort on the unit column of any field first, all such foreigners are removed on the first sort; after this, when sorting on the tens column, cards from 1 to 9 will be found in this box if there is no naught position punched in the tens column.

Each pin in the pin box may be retained out of action by lifting it free from a bridge which extends across the pin box and engages the second of two slots in the pin holder, and then by lowering it so that the second slot engages with the bridge. This is done in two seconds without any disconnection of springs or undoing of nuts or screws.

The speed of operation is over 20,000 cards per hour on one column, it being necessary, of course, to sort twice if two columns,

and six times if six columns are punched in the one field; thus with cards numbered from 1 to 1,000,000 there would be six sorts, or an overall speed of 3,333 cards per hour, which means a little over thirty hours' work for one machine to place 1,000,000 cards in consecutive order; a million cards would make a pack 583ft. high with cards of the thickness used.

In the English census and Welsh census of 1921, 38 million cards were punched, 890 millions were sorted, and 300 millions were counted. Numbers are merely an added justification for the use of Powers machines.

When required, a series of counters may be fitted to the side of the machine, one corresponding to each box, together with a sub and grand total counter; these count the number of cards passing into each box, and may be used in some cases to add the numerical value of the whole by multiplying the counter number by the cards passed; this procedure is not advised, because clerical error is possible both in copying down the results and in the calculation. All the counters are easily zeroised, and may be easily retained out of action.

Fig. 3 shows also a piece of extra equipment in the shape of a rack placed on a wheeled stand; the partitions are positionable directly under the card boxes of the machine and are similarly numbered so that when large numbers of cards are being dealt with the boxes may be emptied and the cards transferred to the rack with a minimum of confusion and without stopping the machine.

The Tabulator Printer.

The tabulator printer performs the final operation, its function being to reproduce in legible form the meaning of the holes that have been punched into the card. In this case a list of desirable features would be so formidable that it will not be attempted; we might like to have, for instance, a machine that would extend rate and hours into cash, add a percentage and deduct insurance, etc., these cannot be done at the moment, but the future will see many improvements

The machine in its essentials consists of three main assemblies :—

(1) The adding machines.

(2) The sensing apparatus.

(3) The connection box between the two.

The adding machine is constructed on the well-known Dalton principle, and in the largest machine consists of seven groups of figures or units each containing ten figure sections. These units may be decimal adding, £ s. d. adding, or alphabetical, as may be required; each will print all the information punched into the card and will add and print the totals when desired.

The sensing apparatus contains also the card feed, and consists

of two sets of pins, each set containing a pin for every possible position in the card. The top set of pins when raised by the lower ones passing through the card lifts the wires of the connection box and so controls the movements of the adding machine.

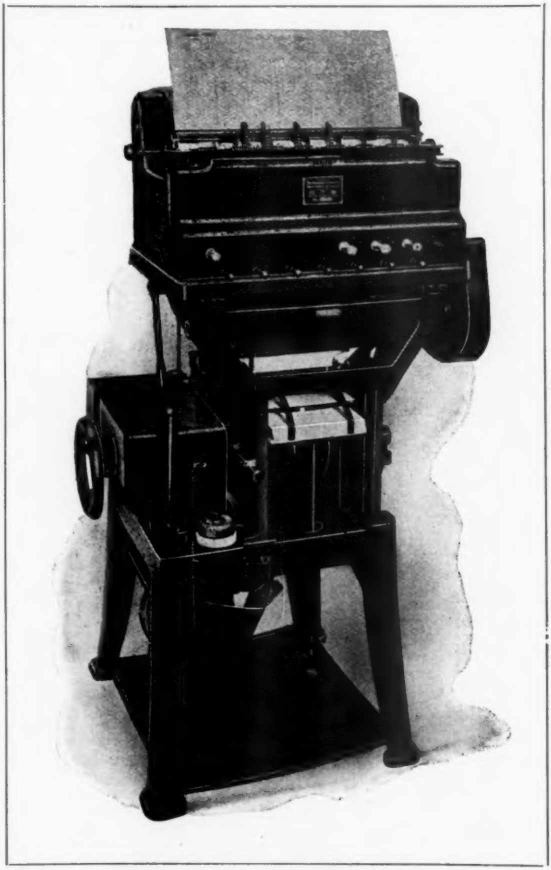


Fig. 4.—A tabulator printing machine.

The connection box is a simple unit consisting of an aluminium casting containing a number of wires which are arranged to connect the card positions of the sensing mechanism with the positions of

the adding machine. By this means entirely different card forms may be used on the same tabulator, and the change may be made rapidly and without error by a girl operator, because no incorrect connections are possible with the unit construction provided.

The movements of the whole machine are as follow : The card is fed by the previously described knife and throat arrangement between the pin plates and the connection box wires lifted as mentioned above; these in turn raise one of the stops in each row, which stops are positioned under the swinging figure sectors, and by means of the heel on the sector bring the sector to rest with the figure corresponding to the hole punched in the card opposite the centre line of the paper roller. The hammers are then released, so that every type so positioned receives a blow and prints on the paper through a ribbon. Naught shutters are provided, which hold the sectors back until one of the stops is lifted, and provision is made to prevent the hammers from actuating when the sector is not released.

The adding function is controlled by the gear teeth cut in the bottom of the sector, the accumulator wheels are geared in with these teeth just before the sector is returned to its normal position, and consequently wind in the amount to which the sector has been extended. On a total stroke this procedure is reversed and the accumulator meshed with the sector at the beginning of its forward stroke, allowing the sector to move as far as the amount previously wound into the accumulator will allow it. Provision is made for the necessary carry-over from one sector to the next by allowing the sector which has to receive the extra movement to restore a distance equal to one digit beyond the usual position of rest, allowing an extra movement of one tooth of the accumulator to be wound in as the sector comes to its rest position.

Without describing them in detail, many useful functions and controls are provided on the machine which greatly add to the efficiency.

1. Automatic stop when the magazine is empty.
2. Grand totalling mechanism.
3. Subtraction device.
4. Retention and printing of designation of the first card in a batch.
5. Listing in full or printing totals only.
6. Prevention of any unit from adding.
7. Prevention of any unit working at all.
8. Prevention of any digit from printing.

The inclusion of an alphabetical unit allows a name of ten letters to be printed, and if the total card be punched, a different word may be printed on the same line of the total, other than the designation of the card; thus on sales analysis the names of the

commodities may be printed by the cards, and the name of the customer printed by the total card.

The speed of operation is sixty items per minute, which is continuous, the only wasted time being idle strokes to leave spaces before and after totals. The machine may be left to run continuously without attention other than the feeding of cards to the magazine and replacement of sheets of paper when the continuous roll is not used.

I need not go into the question of the necessity for costing, which is so well appreciated by all production engineers. I will assume that the annually prepared oncost is dying with its blood relation the annual balance sheet, and that weekly or monthly figures are necessary for correct control of manufacturing.

As a generalisation the work to be performed is as follows :—

Labour.

To collect in descending order of man's number and total by departments the details for the wages sheet.

To each man's quarterly earnings for income-tax returns.

To collect all labour charges under their job number process or overhead account.

To obtain statistics such as average labour cost per hour, indirect labour as a percentage of direct labour, or value of product, idle time analysis, and lost time reports.

Material.

To debit main stores with purchases.

To credit main stores and debit sub-stores with materials supplies.

To debit job, process, or account and credit sub-stores.

To obtain stock-taking figures.

To compare buying prices and consumptions against previous records.

Overheads.

To collect details of labour and material under the correct account.

To allocate depreciation, interest, and other expenses departmentally.

To collect items of machine rate, floor rate, or any other method of charging oncost.

To add all oncosts, however charged, to the correct manufacturing cost or account.

General.

To provide checks or double entries between all internal accounts.

To record production, rejection, and good work, and produce comparison.

To produce mileage statistics, costs, and petrol and tyre consumption, for motor vehicles.

To control distribution of railway wagons and returnable empties of value.

To control finished part stock and ready for sale stock.

To control small tool usage throughout the factory.

The wages sheet to-day is as variable as any other clerical production, varying as it does with the methods of payment, such as time rate, premium bonus, piece work, and others, but the greater part of the clerical work involved is in the preparation of the sheets with the standard insurance and other deductions, which, in their turn, have to be posted to some form of ledger account for each individual.

Following the previously mentioned principle of mobility, it is desirable to have the standard data on one card and the variable on another, but this is by no means essential in some instances. For the purpose of demonstration we will produce a few entries of a simple nature showing gross deductions and nett amount payable only.

There are other schedules on view to show that the difficulties can be overcome, but as there are many different jobs to be shown on this one tabulator without change of connections or automatic naughts, some latitude must be allowed. In the case of piece work payments the rate setter usually originates the Powers cards, which then pass to the shop *via* the planning department, and have the actual time added by means of time clocks or the foreman. In this case there is a rough tabulation made after a sort on man's number to collect the total payable; this total is then punched into a card which bears already the standard deductions. or these latter may be gang punched simultaneously with the detail punching. Bonus payments are often made a separate payment and relate to a different time to the wages cards; the production of a bonus pay roll as a separate item is to be recommended. Whatever method is employed it is advisable so to design the scheme that as much preparatory work may be done during the week as possible, thus reducing the rush at the end of the week.

The sheet shown in the machine is now being produced at 60 entries per minute, so that the actual time required for printing is lower than any other method. Furthermore, departmental totals and a grand total may be given by the machine from which to draw the money for payment, and to give certain comparisons which are in themselves a check. While on this subject I will mention one special check which is applicable specially to wages. If all the cards are sorted by rate and tabulated, a total of hours at each rate and the total cash will be given. An extension of the

hours at the rate should then check with the total cash. If the cards are also in descending number of hours the errors, if any, can be seen immediately by inspection.

For income-tax returns it becomes necessary to add the gross amounts paid to each man during thirteen weeks, a difficult and costly business by hand methods, but the thirteen weeks' cards for a thousand men may be sorted in a little over two hours and

Fig. 5.—A group of cards.

tabulated in four and a-half hours on one machine, not a serious work for a quarterly return.

The operator will now sort and tabulate such a return putting in the space and total cards by machine. Now of these men some are on productive work on job or operation and are changing jobs frequently; for such, unless they are on piece work, it is better to use a separate clock card from that recording attendance. There will be others who are sweeping the shop or stoking the

boilers whose time must be debited to a certain oncost or nominal account as a weekly total, if there is a field allowed for this account number the same cards may be used for posting direct to these accounts.

Where a separate clock card is used for job or process costing a different design of Powers card will be used, corresponding to the requirements of the business. There is no reason at all why the Powers card should not be the original record containing the foreman's written instructions, the time stamped by a Gledhill or other time clock, and the hours at a rate may be extended into cash; all this work can be done by the time office in the works, who will then punch the card on the Powers printing punch, thus providing the cost office with an accurate and finished card wherewith to work.

There is no need to describe at length how such cards would be used, the operations of sorting and tabulating have already been demonstrated, it is sufficient to say that the cards would be sorted on man's number and tabulated weekly, thus providing a check against the wages sheet; this is valuable, because all anxiety as to whether the costs will balance the expenditure is removed by this check.

One of the drawbacks of many methods of costing is that a large amount of work has yet to be done after the closing of the job to be costed, another is the large amount of detail extending necessary. Two principles may be applied when using mechanical appliances such as we are investigating, but the extent to which they are used depends upon circumstances.

By the Powers method the work done in each week, month, accountancy period, or other convenient division of time, may be tabulated under job number, and the total expense in labour, material, and oncost may be punched into a summary card. The tabulated sheet is filed as a record in case an enquiry into detail is wanted, but, of course, such detail sheets may be produced at any subsequent time by passing the cards through the tabulator. If now the work runs for these periods, there will only be the cards of the last period and two summary cards to pass in order to obtain a full cost.

I have strayed from the consideration of labour cost somewhat, but must mention the use of the machines for collecting together all labour at the same rate of pay in order to allow of extending in bulk.

In process costs particularly a month by tonnage may have to be costed, and there is little or no advantage to be gained by punching summary cards for a shorter period, each operation may have a dozen men at the same rate working for the whole month and as many helpers at a lower standard rate. Realising that detail is obtainable at any time, we may sort the cards on the rate

-I.P.E., The Mechanical Compilation of Costs.

JOB COSTING

Day	Mth.	Job No.	Quant.	Unit	Man or Material	No. or S.L. Folio	Labour £	s.	d.		Material £	s.	d.		Oncost £	s.	d.
23	8	2256	47	Hours	Thomas	146	3	1	6						4	12	3
23	8	2256	23	Hours	Watts	247	1	10	10						2	6	3
23	8	2256	4	Hours	Reeves	332		4	0							6	0
23	8	2256	8	Lbs	Yel Brass	1243						6	8				
23	8	2256	4	Lbs	Mild Steel	8846							8				
23	8	2256	4	Iron	Castings	27						8	3				
					Repairs to Plant		4	16	4	*		15	7	*	7	4	6

WAGES SHEET (INCOME TAX RETURN).

Dept.	A/c.	Day	Month	No.	Name	Hours	Rate s.	d.	Net £	s.	d.	Gross £	s.	d.
				1236	Armitage							38	0	3
				1237	Atkinson							37	13	7
				1238	Boucher							30	5	0
				1241	Chick							32	8	7
				1246	Dauey							35	8	8
				1247	Dormer							37	17	0
				1248	Saunders							27	15	7
				1249	Scaife							30	8	0
				1253	Tatlow							30	4	3
				1256	Thompson							25	1	1
				1257	Munroe							22	15	2

No.	Name	£	s.	d.
1247	Dormer	37	17	0
1248	Saunders	27	15	7
1249	Scaife	30	8	0
1253	Tatlow	30	4	3
1256	Thompson	25	1	1
1257	Munroe	22	15	2
1259	Newton	30	9	6
1261	Patterson	22	14	6
1262	Tilley	20	7	5
1263	Watson	37	12	4

WAGES SHEET.

Dept.	A/c.	Day	Month	No.	Name	Hours	Rate s.	Rate d.	Net £	Net s.	Net d.	Gross £	Gross s.	Gross d.
18	3	19	July	1236	Armitage	4700	1	3	2	17	2	2	18	9
18	3	19	July	1237	Atkinson	4700	1	3	2	16	11	2	18	9
18	14	19	July	1238	Boucher	4675	1	0	2	5	3	2	6	9
18	7	19	July	1241	Chick	4325	1	1	2	5	7	2	6	7
18	11	19	July	1246	Dauey	4700	1	2	2	12	1	2	14	10
18	12	19	July	1247	Dormer	4450	1	3	2	17	3	2	18	8
18	4	19	July	1248	Saunders	4700		11	2	1	7	2	3	1
18	6	19	July	1249	Scaife	4625	1	0	2	4	6	2	6	3
18	7	19	July	1253	Tatlow	4525	1	0	2	3	10	2	5	3
18	3	19	July	1256	Thompson	4600		10	1	16	3	1	18	4
18	4	19	July	1257	Munroe	4500		9	1	11	1	1	12	11
18	7	19	July	1259	Newton	4675	1	0	2	5	5	2	6	9
18	18	19	July	1261	Patterson	4300		9	1	10	0	1	12	3
18	12	19	July	1262	Tilley	4000		8	1	5	3	1	6	8
18	4	19	July	1263	Watson	4700	1	3	2	17	7	2	18	9
18	3	19	July	1264	Young	4600	1	3	1	15	1	1	17	6
18	6	19	July	1265	Butler	4700	1	2	2	13	2	2	14	10
18	7	19	July	1266	Ronald	4550	1	1	2	7	10	2	9	4
18	18	19	July	1267	Marles	4300		11	1	18	1	1	19	5
18	12	19	July	1269	Pearce	4700		9	1	11	10	1	13	7
18	4	19	July	1276	Storey	4700	1	0	2	5	8	2	7	0
18	4	19	July	1278	Whittaker	4700		10	1	17	9	1	19	2
									* 47	19	2	* 49	15	5

[To face p. 236.

and extend the total hours at each rate, thus reducing clerical labour and chances of error to a minimum.

Many statistics, such as departmental wages totals, average labour rates, and percentages of direct and indirect labour, are obtainable by a few hours' machine work from the same cards. The same principles are used in the handling of material charges, the cards being used for the double purpose of debiting the job or process and crediting the raw material ledger or perpetual inventory, the debit side of the latter being provided by an analysis of the purchases.

The Powers card may be utilised as the actual stores order, being punched later for tabulating purposes, the usual duplicate copies for one purpose or another being replaced by periodical tabulation under commodity number. One user of Powers machines who makes considerable use of displayed boards uses a special installation of laryngaphones, by which those in control of stocks of materials or finished parts may dictate to the punch operator their stocks from the points of control, thus utilising the machines for rapid stock taking.

The collection of indirect material and labour is carried out in the same way as described above, the allocation being on oncost number or nominal account number. It is desirable that every charge which goes to the make up of oncost shall go through the material or stores ledger, from which it may be allocated according to requirements; thus if a departmental hourly rate be required the stores ledger would be debited with a total amount of depreciation, interest, insurance, and other expenses, and allocated departmentally on Powers cards on floor area or other distribution decided upon. Then the departmental total oncost is obtained on the tabulator and divided by the departmental productive hours also obtained by tabulation. Full double entry accounts may be kept throughout all accounts, and in such cases as the stores ledgers an automatic balance of goods in stock may be given on the tabulator. The uses of the cards are not restricted to the cost accounts only, but the totals, either as punched summaries or as totals from details, may be used to prepare the financial books of the company.

PROVINCIAL BRANCHES

COVENTRY BRANCH

Chairman : MR. T. SYKES, Beresford House, Priory Road, Kenilworth, Warwickshire.

Vice-Chairman : MR. R. HURRELL, 12, Chester Street, Coventry.

Committee :

MR. E. V. DODMAN, The Hillman Motor Car Co., Ltd., Pinley.

MR. H. BARRAND, 11, Friars Road, Coventry.

MR. W. ELLIS, The Ford, Castle Road, Kenilworth.

MR. P. A. SHAW, The Hillman Motor Car Co., Ltd., Pinley.

Hon. Secretary : MR. J. M. MESTON, Priory House, Priory Street, Coventry.

LIST OF MEETINGS held before the Coventry Branch during 1924–25 :

Date.	*Subject of Paper.*
1924.	
Nov. 12.. ..	"Industrial Diamonds," by R. Shaw, London.
Dec. 2	"Machine Tools and Production," by I. H. Wright (Smith & Coventry, Ltd.).
1925.	
Jan. 13	"Accuracy in Production Engineering," by J. E. Baty, London.
Feb. 10	"Drop Forgings," by Bernard Brett, Coventry.
Mar. 10	"Centreless Grinding," by W. Ogilvie (B.S.A. Tools, Ltd., Birmingham).

CENTRELESS GRINDING.

By W. OGILVIE, of B.S.A. Tools, Ltd., Birmingham.

The development of grinding as a process for the production of interchangeable parts, for quickly removing metal, and for finishing a diameter or surface to within fine limits, has been one of the most notable advances in machining methods of the last few years.

In considering such parts as rollers for bearings, roller chains, etc., the extended use of these is largely dependent on the attainment of the highest degree of accuracy at the lowest possible cost. A large number of ground parts are required, which have only one diameter to be ground. In some cases this diameter extends the whole length of the piece, and in others, such as bolts, etc., it is necessary to grind the smaller diameter to a shoulder.

Such parts have in the past been dealt with on a centre grinding machine. Short pieces up to 5in. long have usually been produced on a machine in which a wide wheel is used, with only a small oscillation of the table or spindle, to clear the wheel whilst grinding. The feed of the grinding wheel is straight in, and not intermittent, as in the case of the table traversing grinding machine.

If a machine of this type be considered, it is found that the actual time taken for the removal of metal by the most suitable grinding wheel is extremely short. This time, however, is only a small proportion of the actual time cycle per piece. The carrier for driving the work has to be attached, the piece mounted between centres in the machine, the work head started up, and the grinding wheel brought into contact with the work. In grinding comparatively short pieces, the above operations take from 50 to 100 per cent. of the time occupied by the actual operation.

Hitherto improvements made to centre-grinding machines to increase production on repetition work have been largely in the direction of fitting dimension stops or automatic electro-magnetic sizing devices. Such improvements, however, only effect a saving of a small proportion of the total time of the operation, and it is, of course, the total time that matters.

Centreless grinding machines have been developed with the object of making the actual grinding time a much greater proportion of the total piece, the great advantage being that grinding is

continuous. In considering such machines it is necessary to separate the work into two classes, namely :—

(1) Cylindrical work of one diameter, such as rollers, gudgeon pins, etc., which can be passed through the machine from one side to the other. On this type of work the operation of the machine is truly continuous.

(2) Cylindrical work having one or more diameters to be ground, which it is essential should be true with each other, but not necessarily true with a third diameter. The machine is then used in a similar manner to the centre grinding machine, having a broad face wheel. The grinding wheel is advanced to the work against a definite stop, but the work is supported in a special form of work-holder and not by centres. The actual operation of placing the work in position and removing it is three or four times faster than in the centre grinding machine, and no driving arrangement is necessary.

On the centre grinding machine the object of the centres is to support the work against the pressure of the grinding wheel and to enable the work to be revolved in opposition to the wheel. In centreless grinding machines it is necessary to support the work against the pressure of the grinding wheel and also to revolve it, and there are many different methods of doing this. This principle of so-called "centreless grinding," like many other processes, is not new, such devices having been used for grinding corks, for example, for many years.

One of the earliest types of centreless grinding machine is shown in fig. 1. The grinding wheel is similar to that used on a centre grinding machine, the periphery being tapered so that the wheel is 16in. diameter at one side and 15in. at the other; the face width is 5in. A work-holder consisting of three hardened steel plates is employed, these plates forming a triangular channel or dovetail in which the work to be ground can slide. The back plate or base of the triangle is adjusted so that only just sufficient of the work projects beyond the bottom plate to enable the required amount to be ground off.

As shown in the enlarged view, the work travels on the edge of the lower plate, which is bevelled at 45 degrees away from the wheel. The back plate takes the pressure of the grinding wheel, whilst the top plate, which is a duplicate of the bottom plate, acts as a guard to prevent the work falling away. If the work is inserted into the work-holder and contact made with the revolving grinding wheel by means of the cross-slide on which the work-holder is mounted, the work will revolve with the grinding wheel, and not against it, as in the case of centre grinding machines.

The question of traverse has not yet been considered. The work-holder is set round so that the work in passing through will make contact with the coned periphery of the wheel. It is also

tilted at an angle of approximately 5 degrees to the horizontal axis of the wheel spindle, and the work is fed in at the high side of the holder. Owing to the axis of the work being inclined to the axis of the wheel, the piece in passing through the work-holder would only make contact at the centre of the grinding wheel. Before grinding takes place, therefore, it is necessary to true the wheel from the work-holder by passing a diamond across the face in exactly the same path as that to be taken by the work. The effect of this will be to make the periphery of the grinding wheel slightly concave according to the degree of tilt given to the work-holder.

If the cross-slide is now adjusted to take a light cut and a piece

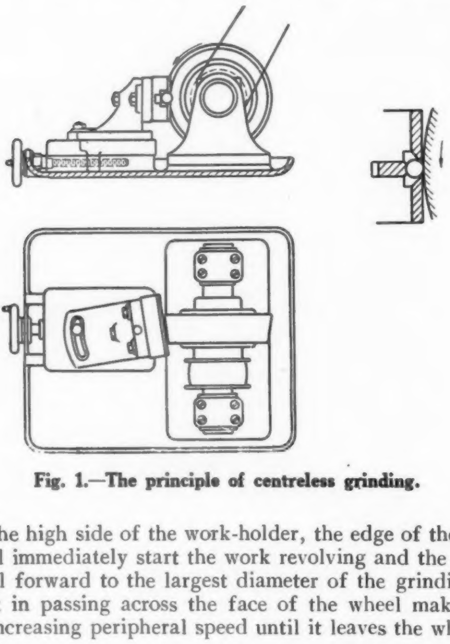


Fig. 1.—The principle of centreless grinding.

fed into the high side of the work-holder, the edge of the grinding wheel will immediately start the work revolving and the piece will also travel forward to the largest diameter of the grinding wheel. The work in passing across the face of the wheel makes contact with an increasing peripheral speed until it leaves the wheel at the other side.

In actual practice, it is found that the speed at which the work will revolve depends on the cut which is being taken, and if too heavy a cut be attempted the work will not revolve fast enough, so that flats will be formed instead of a true cylindrical surface. The grinding action which takes place is dependent upon the braking effect of the back plate. This controls the speed at which

the piece revolves according to the pressure between the wheel and the work.

To obtain the highest efficiency in a centreless grinding machine it is necessary to restrain the work against the action of the grinding wheel to rotate it. There is a very intimate relation between the speeds of the grinding and control wheels, which determines both the rate of output and grade of finish.

The principal units of a modern centreless grinding machine are : a grinding wheel, a regulating wheel, and a work rest. The grinding wheel presses the work against the work rest due to the resistance of the cut and also against the regulating wheel. This wheel is, in some machines, made of steel, and in others of a

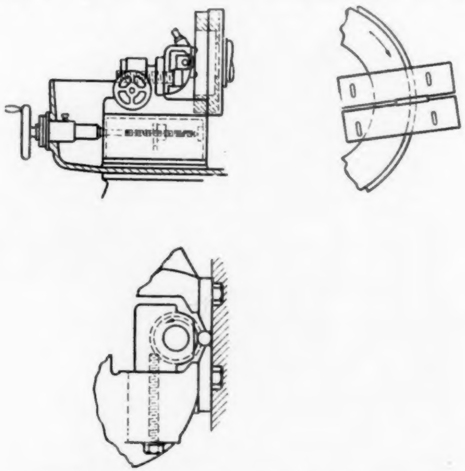


Fig. 2.—Grinding with a face wheel and driving roller.

material similar to the grinding wheel, which, having a higher coefficient of friction, will tend to control the speed of the work to a greater extent. By varying the speed of the regulating wheel it is possible to control the grinding conditions, and the rate of rotation of the work is adjusted in this way.

The machine shown in figs. 2 and 3 also works on the principle that the grinding wheel grinds and traverses the work. In this machine the wheel is of the face type, the width of the face being 3in. The work-holder consists of a top and bottom plate similar to the ones used on the machine previously described, but the back plate is replaced by a hardened steel roller, this roller being independently driven by means of a three-step cone and universal joint

shaft. The work-holder is mounted in such a manner that the path of the work can be exactly radial to the centre of the wheel or can be tilted to a varying amount from this position. If the axis of the work is radial, only rotation will result, whereas, if the

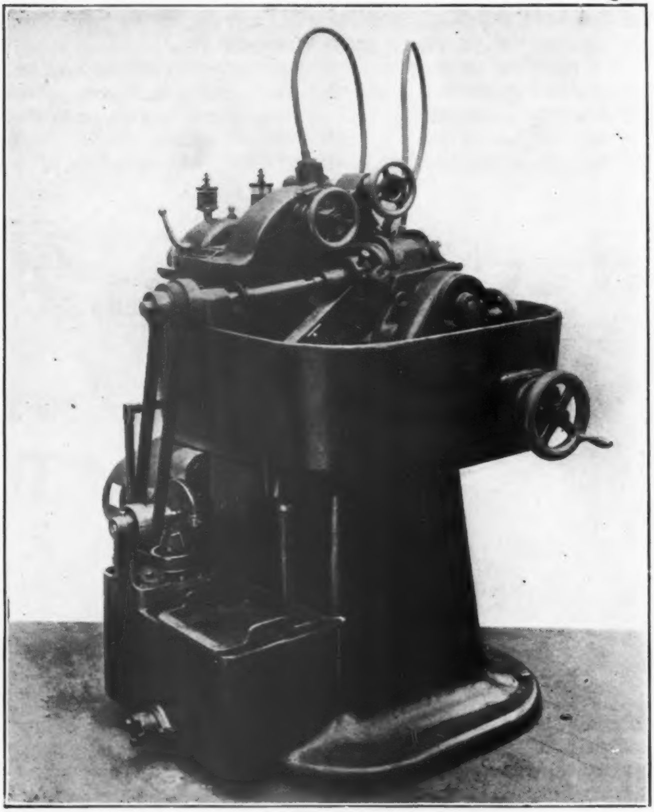


Fig. 3.—A modern centreless grinding machine.

work is passed at right angles to the radial position, only traverse will occur, so that an intermediate position will give any desired combination of rotation and traverse. This arrangement has the additional advantage that the various movements of the work-holder do not interfere with retruing the wheel face. Further, the

surface speed always remains the same as the wheel is worn down, and the roughing and finishing traverse can be obtained without redressing wheels.

By means of the driven roller it is possible now to control the speed at which the work revolves, and, by means of the three changes provided, the best speed can be found for producing the finish required on the particular diameter of the work being ground on the machine. This machine is particularly suitable for chain rollers and rivets, rollers as fitted to roller bearings, gudgeon pins, and all straight-through work up to 1¼in. in diameter by 6in. in length.

A machine of the same type is also built as shown in fig. 4, and is suitable for straight-through and shoulder work, with a work-

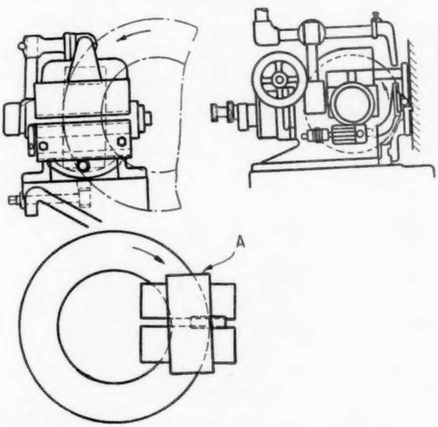


Fig. 4.—The action of the face wheel.

holder having a governing roller A of abrasive material. In this case the axis of the roller is set at approximately 3 degrees to the centre of the face-grinding wheel, and is not capable of being tilted from this position. The work plate is mounted on a circular seating such that the path of the work can be inclined up to 5 degrees in relation to the axis of the roller, a normal inclination being about 2 degrees.

The effect of this is to cause the work to be both rotated and traversed by the governing roller, means being provided so that the roller can be trued. As previously mentioned in the case of the first machine, the work will make contact at every point across the face of the roller. The truing device in this case is carried at

the reverse side of the wheel to the work, and is mounted in a slide which is set to the same inclination as the work plate. Another point is that the diamond holder is carried in a slide on the wheel guard so that the truing up of the wheel can be done at any time without disturbing the position of the work slide.

The next type of machine for centreless grinding is that in which the peripheries of two abrasive wheels are used for grinding and controlling respectively, as shown in fig. 5. In this case, the work to be ground is supported by a plate between the two abrasive wheels, and the edge on which the work slides is parallel with the axis of the grinding wheel, but can be adjusted vertically. The governing or controlling wheel is mounted in a swivelling head so that its axis can be parallel to the grinding wheel spindle, or can

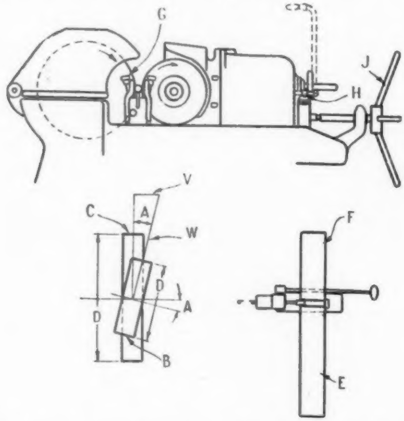


Fig. 5.—A machine with tilting governing wheel.

be set at any desired angle to the axis of the spindle Thus when the governing wheel is swivelled at an angle, it will be found that, owing to the fact that it revolves away from the work or in the same direction as the grinding wheel, according to the amount of tilt, a definite traverse will be given to the work.

As the work plate of this machine always remains parallel to the spindle of the grinding wheel, it will be clear that this wheel can have no influence whatever in determining the traverse of the work. The axis of the controlling wheel, however, can be moved in relation to the work. In order, therefore, that the piece shall make contact with the periphery of this wheel whilst travelling along the support, it is necessary to make special provision to true the wheel after any alteration of the rate of traverse.

In considering what is the proper line of contact between the work and the wheel relative to its centre, it is found in practice when dealing with work up to $1\frac{1}{2}$in. diameter, that the best results as regards finish, roundness, and the minimum of wear on the bottom plate, are obtained by making the line of contact from a quarter to half the diameter of work above the centre of the grinding wheel. In the case of the face wheel machine, the line of contact should be the same amount above the centre of the controlling roller.

As the width of the controlling wheel is usually made the same as the grinding wheel, it is necessary to provide adjustable guides which, together with the supporting plate, will form a channel in which the work will rest before reaching the grinding wheel and after leaving it. The adjustment of these side supports should

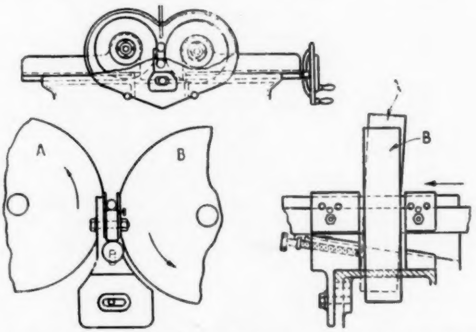


Fig. 6.—A machine with grinding and governing wheels at a fixed angle.

be carefully carried out, as when grinding fairly long work it is essential that the two side guides on either side of the control wheel shall be correctly adjusted, so that there shall be a continuous path for the work along the guide to the other side.

The necessity for an adequate supply of coolant on a centreless grinder is more pronounced than on any other machine. This is probably due to the need for completely flushing the work-holder in addition to cooling the work.

Another machine, the principle of which is similar to the above, has certain distinctive features of design. As shown in fig. 6, the grinding and controlling wheels are of the same size, *i.e.*, 16in. diameter. The spindles are mounted in two slides on each side of the central work fixture, so that either control wheel or grinding wheel can be adjusted independently in relation to the work-holder. The spindle of the controlling wheel is permanently set

at an angle of 3 deg. in the horizontal plane with regard to the grinding wheel spindle, and this fixed position of the regulating wheel has been found quite satisfactory for the average run of work. Provision is made for obtaining different speeds to the control wheel, so that the surface speed of the work relative to that of the grinding wheel can be adjusted to obtain the finish required.

In this, and all other centreless grinding machines in which the controlling wheel is of abrasive material, provision is made for running the wheel at a reasonable speed so that it can be satisfactorily trued up by means of a diamond. In the present instance the diamond holders are carried on slides at the back of the wheels, the slides being fitted with adjustment so that the control wheel can be trued up until the work makes contact right across the face of the wheel.

Some consideration of the comparative times between the centreless and centre grinding methods may be of interest. In a general way it is fair to state that more allowance has to be made on work ground between centres than on the centreless machine, for, whereas 0·010in. to 0·015in. is usual in the first case, 0·008in. to 0·010in. is frequently satisfactory for the centreless method.

In centreless grinding it is usual to pass the work through the machine three or four times to obtain the finish and size required, adopting a grinding allowance as stated above. The wheel employed is very much finer than that used on the centre grinding machine, being approximately 120 M. or 80 K.C. rubber bonded. It is also an advantage for the sizing pass to be taken with an even finer wheel.

Among the advantages claimed for the centreless method are the following, and these directly affect the quality of the work produced.

1. It is only necessary to leave about half the usual amount of grinding allowance. This feature is particularly valuable when dealing with case-hardened work.

2. The metal is not removed by crowding the wheel on to the work, but by two or three comparatively light cuts. There is thus less danger of developing grinding cracks.

3. By the use of a harder wheel, and also by taking a finer sizing cut (the amount of metal removed being approximately 0·001in. to 0·002in., and in some cases even less), the grinding wheel may be made to maintain its size for a very long period.

4. The work is supported throughout the whole of its length by the work plate and governing roller.

There is one point in connection with the quality of work produced, which in the case of the centre grinding machine it is usually not necessary to check, and that is the roundness of the work. It can be stated that a centreless grinding machine will grind parts to within a tolerance of 0·0002in., provided they are

reasonably straight and round when brought to the machine. In the case of rollers for roller bearings the tolerance is considerably less.

Difficulty in the production of round work can usually be traced to one or other of the following causes :—

Faulty adjustment of the grinding wheel spindle bearings. The spindle bearings are of the utmost importance, as in the case of all other grinding machines, and good work cannot be obtained unless particular care is taken of this part of the machine.

Incorrect setting of the side guides which lead the work between the governing wheel and grinding wheel and also meet it at the other side.

The governing wheel running out of truth.

The relative position of the work centre to the governing wheel or roller. This should be above rather than below centre.

Work supporting plate requires grinding up.

In the case of shoulder grinding, in addition to the above points, particular attention should be paid to the manner in which the work is fed into the grinding wheel. This should be as regular as possible, and should tend to decrease as the finished size is approached. If the work is crowded on to the wheel suddenly it will be badly thrown out of round.

When designing components which are within the range of the centreless grinding machine, the best results will be obtained if one or two points are considered, as it has been found by experience that by slight modification to certain articles it has been possible to take advantage of this process when it would not otherwise be practicable. For example, concentric and spirally grooved parts present no difficulty, but an oil groove which is parallel with the axis of the article to be ground tends to cause a slight chatter when the work is revolving if too heavy a cut is attempted. All oil grooves should, therefore, be spiral. Transverse slots across the end of an article, such as those sometimes made in gudgeon pins, will cause a very slight spiral effect to be apparent on the finished article.

The centreless grinding machine should not be looked upon as a machine only of use to manufacturers with a very large quantity of one or several articles. The setting-up time when changing over from one size to another in the case of straight-through work should not exceed 10 to 15 minutes. When changing over from straight-through work to shoulder grinding, this time should not be more than 20 to 25 minutes. It is, therefore, profitable to use one of these machines where a hundred articles only are required at a time.

It is the practice now in a large number of firms to grind long bars of rough material before these are passed to the automatic

machine, or cut up for other operations. This enables material, which it is difficult to obtain cold-rolled to within the usual limits of bright drawn steel, to be ground to size. As these bars can be ground to within *plus* or *minus* 0·00025in. less trouble is experi-

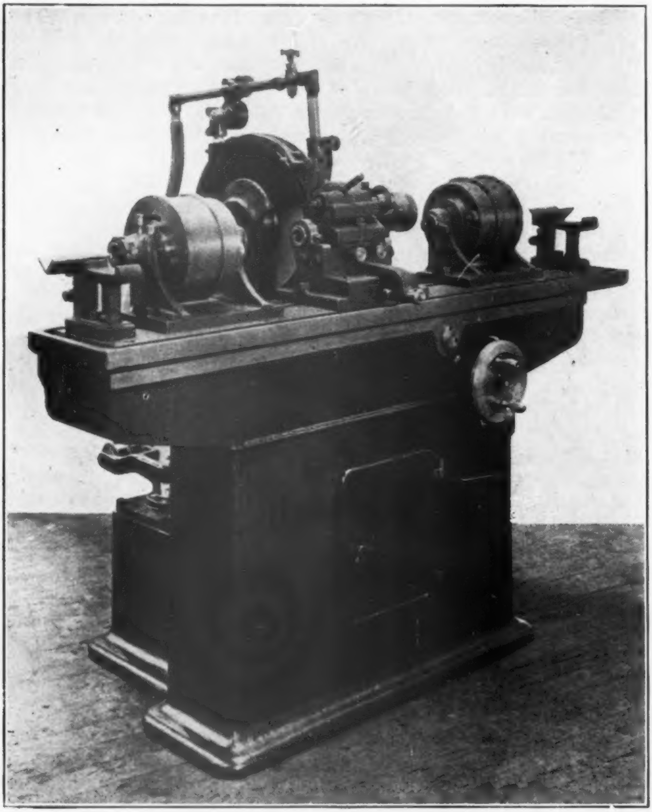


Fig. 7.—A bar grinding machine.

enced with the automatic collets and feeding devices used on automatic machines.

In the manufacture of such articles as taps, drills, etc., the stock can be ground to within 0·005in. of the diameter of the finished article, the remaining amount being removed on a centreless grind-

ing machine after the hardening operation. Machines for this class of work are of the type shown in fig. 7, and are built for taking bars up to 1½in. diameter. The bar is supported in a vee channel and fed into a revolving head at one end of the machine. This head has two rollers which grip the bar, to rotate and traverse it. The bar is fed forward to the steady rest placed in front of the grinding wheel, and the ground portion passed out at the other side of the steady rest into a second revolving head. Production on these machines is approximately 6ft. to 8ft. per minute; bars of 12ft. long being handled satisfactorily. The amount removed per pass is from 0·003in. to 0·005in.

It may be interesting to consider the probable development of the centreless grinding machine, particularly as applied to shoulder grinding. When working these machines the operator performs

Component.	Dimensions of Ground Portion.	Production of Finished Components per Hour.	
		Centre.	Centre-less.
Jobber Length Drills	Up to 0·250in. dia.	—	400
Motor Cycle Valves	0·281in. dia. by 3·750in.	30	80
Gudgeon Pins ...	0·750in. ,, 3·750in.	30	150
,, ...	0·500in. ,, 2·375in.	60	200
,, ...	1·000in. ,, 3·750in.	30	120
Pins	0·500in. ,, 1·875in.	60	250
,, ...	0·500in. ,, 2·000in.	60	230
,, ...	0·625in. ,, 2·250in.	80	180
Bolts	0·500in. ,, 3·000in.	45	120
Pins	0·750in. ,, 1·750in.	60	200

the following movements:—The work is placed upon the rest between the two opposed abrasive wheels. By means of the feed lever the work is then brought into contact with the grinding wheel, the feed being continued until a fixed stop is reached. The feed lever is next returned to its original position, and a knob depressed which causes the work to be ejected from between the wheels.

It is possible for a machine to be built which will carry out all the above operations automatically, the operator only having to place the work on the work rest between the wheels. This machine would, therefore, be a semi-automatic grinding machine. With a sufficient quantity of work, a hopper feed could be arranged into which the operator would load a sufficient number of components for the machine to operate for a period of three to four minutes. If desired, it would be possible for him to look after two or three machines. The articles could be fed into the machine twice, once

for rough grinding, within, say, 0·002in. of size, and again for finishing. For this operation the machine should be fitted with a special finishing wheel.

For shoulder grinding it is usual for the width of the wheel to be equal to the length of the work to be ground. Machines are now supplied with wheels having 5in. or even 6in. faces, and it is very desirable that such machines should be fitted with a diamond truing device operated by power, as the fine truing of both wheels has a marked effect on the quality of the work produced.

A useful comparison between the production times for centre and centreless grinding respectively is given in the accompanying table. The tolerance in every case is within 0·0002in. with regard to roundness, diameter, and parallelism. In producing rollers for bearings to a tolerance of 0·0001in. an output of 20,000 per week may be obtained with one machine, the size being up to ⅝in. in diameter.

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Hon. Secretary : Mr. W. Renshaw, 72, Barnby Gate, Newark, Notts.

Papers read at Meetings of the Newark Branch.

"Industrial Diamonds," by R. Shaw. (See Paper read at General Meeting of the Institution at London, Vol. III.)

"Manufacturing a Motor Cycle," by C. S. Boyd.

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† Has read a Paper before the Institution (London).
‡ Has read a Paper before the Newark Branch.
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(I.) OBJECTS.

The objects for which the Institution is established are :—

(*a*) To promote the science and practice and raise the status of engineering as applied to production; and to initiate and carry through any scheme or to organise any movement likely to be useful to the members of the Institution and to the community at large in relation thereto.

(*b*) To hold meetings of the Institution for reading and discussing communications bearing upon engineering as applied to the matters enumerated in paragraph (*a*), or the application thereof, or upon subjects relating thereto.

(*c*) To enable engineers to correspond, and to facilitate the interchange of ideas respecting improvements in the various branches of the practice of engineering as applied to production, and the publication and communication of information on such subjects to the members.

(*d*) To establish scholarships, organise lectures, hold examinations, to grant premiums and prizes for papers and essays, and by any other similar means to enlarge the knowledge and improve the practice of engineering as applied to production.

(*e*) To establish, undertake, superintend, administer, and contribute to any charitable or benevolent fund from which may be made donations or advances to persons at any time employed by the Institution, or who are or may have been engaged in engineering work and are not members of the Institution.

(*f*) To establish, subsidise, promote, co-operate with, receive into union, become a member of, act as or appoint trustees, agents, or

delegates for, control, manage, superintend, lend monetary assistance to, or otherwise assist any associations and institutions incorporated or not incorporated with objects altogether or in part similar to those of the Institution, and which may prohibit the payment of dividend or profit to its members at least to as great an extent as such payment is prohibited to the members of the Institution.

(*g*) To establish, form, and maintain a library and collection of models, designs, drawings, and other articles of interest in connection with the development and improvement of production.

(*h*) To encourage the settlement of disputes by arbitration, and to act as or nominate arbitrators and umpires on such terms and in such cases as may seem expedient.

(*i*) Generally to protect the interests of engineers, and especially engineers engaged in production work (including design and advice).

(*j*) To alter or enlarge the above objects or any of them as may from time to time be found necessary and expedient, having regard to the progress of the Institution.

(II.) RULES.

MEMBERSHIP.

1. The Institution shall consist of Honorary Members, Ordinary Members, Associate Members, Graduates, Associates, Affiliates, and all of whom are included in the term "membership" and members.

2. No honorary member, associate member, graduate or associate, or affiliate, shall, by reason of being legally a member of the Institution, be entitled to any privileges other than those which by these rules attach to the specific class of members of the Institution to which he belongs, and wherever the term "member" is hereinafter used without qualification, it shall be taken to mean ordinary member, and exclude honorary members, associate members, graduates, associates, and affiliates.

3. The Institution may admit such other person as may be hereafter qualified and elected in that behalf as honorary members, ordinary members, associate members, graduates, associates, and affiliates, respectively, but such persons shall sign such form of application as may from time to time be authorised by the Council.

4. The rights and privileges of every honorary member, ordinary member, associate member, graduate, associate, and affiliate shall be personal to himself, and shall not be transferable or transmissable by his own act or by operation of law.

ABBREVIATED TITLES.

5. The abbreviated distinctive titles to indicate the connection with the institution of Honorary Members, Ordinary Members, Associate Members and Associates shall be as follows:—For an Honorary Member, Hon.M.I.P.E.; for an Ordinary Member, M.I.P.E.; for an Associate Member, A.M.I.P.E.; for an Associate, A.I.P.E.

Such abbreviations shall not be used by any member who has resigned or been removed from the Institution, nor may they at any time be used upon any shop front, facia, or sign. If used upon door or wall plates or similar places, the abbreviations shall not exceed 1½in. in height.

CERTIFICATES.

6. Subject to such regulations as the Council may from time to time prescribe, the Council may issue to any Ordinary Member or Associate Member a certificate showing the class to which he belongs. Every such certificate shall be according to the form which may from time to time be approved by the Council, and shall remain the property of, and shall on demand be returned to, the Institution.

QUALIFICATIONS FOR MEMBERSHIP.

Ordinary Members.

7. Candidates for membership as Ordinary Members must be persons not under twenty-five years of age, and must produce evidence to the satisfaction of the Council that they :—

(*a*) Have received a good general education and scientific or engineering training, and

(*b*) Have for a sufficient period held an important position of independent responsibility in the practice of engineering production.

(*c*) Or are, by their attainments, deemed by the Council to be eligible for membership.

Associate Members.

8. Candidates for admission as Associate Members must be persons not under twenty-three years of age, and must produce evidence to the satisfaction of the Council that they :—

(*a*) Have received a good general education, and

(*b*) Have been trained as engineers and have for not less than two years been employed in the practice and science of engineering as applied to production, and shall be actually engaged in the work of such engineering at the time of their application for election.

(*c*) Or are considered by the Council to be qualified for election.

They may be transferred at the discretion of the Council to the class of Members.

Graduates.

9. Graduates shall be persons, not under eighteen years of age, who can show evidence that they are receiving practical training in engineering production, or who otherwise satisfy the Council that there are special circumstances which, in the opinion of the Council, entitle them to admission.

Graduates may not continue as such if they cease to follow such professional calling in production engineering, not in any case beyond the age of twenty-five. They may, however, on reaching this age be transferred, at the discretion of the Council, to the class of Associates.

Associates.

10. Candidates for admission as Associates must be persons, not under twenty-five years of age, who, not having the necessary qualifications for Associate Membership or Ordinary Membership, are or have been connected with design, tool design, research experiment, or organisation for production, and by reasons of their attainments in science or directive ability in manufacture, or works control, have interests in common with production engineering, and are, therefore, deemed by the Council worthy of Associateship.

At the discretion of the Council, they may be transferred, should they become eligible, to the class of Associate Members or Members.

Affiliates.

11. An Affiliated Firm shall be a firm, company, or individual interested in engineering as applied to production, or otherwise interested in the objects of the Institution.

An Affiliated Firm shall be entitled to nominate one member of their staff as an Affiliate for each payment of five pounds per annum to the funds of the Institution, provided always that such Affiliate shall be approved by the Council of the Institution. An Affiliate shall be entitled to attend all meetings in London and the provinces, the Summer Visit, and all visits to works, to receive the "Proceedings" and all other publications, to use the library, and to all other privileges of membership except that of voting and the use after his name of the authorised abbreviations of the Institution as set out in Article 5.

An Affiliate shall not be required to pay an entrance fee.

Honorary Members.

12. The Council shall have the power to elect as Honorary Members persons who, by reason of their past services to produc-

tion engineering, or by other eminent qualifications, are, in the opinion of the Council, eligible for that position.

ELECTION OF MEMBERS.

13. Elections shall take place as often as may be desirable, and they shall be made by the Council.

14. An application for admission to the Institution shall be made according to rules laid down by the Council and on forms to be approved by the Council; such rules or forms to be varied at the discretion of the Council.

15. The Secretary shall forward to each Candidate whose application has been considered and approved by the Council a notification of his election on such form as may be approved by the Council, but the applicant's name shall not be added to the register of the Institution until the entrance fee and first annual subscription shall have been paid. Failure to comply with this article within three months will nullify the election of the candidate.

16. In the case of non-election, no mention thereof shall be made in the minutes, nor any notice given to the unsuccessful candidate.

TRANSFERS.

17. Any member lower than the class of Ordinary Member, or any Graduate, desirous of being transferred to a higher class, shall forward to the Secretary a recommendation according to the rules laid down by the Council. Such recommendation shall be laid before the Council, at their next meeting, for consideration, and, if approved, the Secretary shall forward to the applicant a notice of his transfer, on such form as may be approved by the Council. The transfer will be completed upon payment of any difference there may be in subscription.

18. In the case of non-transference, no mention thereof shall be made in the minutes, nor any notice given to the unsuccessful applicant.

RESIGNATION AND EXPULSION.

19. Any Ordinary Member, Associate Member, Graduate, Associate or Affiliate notifying the Secretary, in writing, that he is desirous of withdrawing from the Institution, shall, after the payment of all arrears, if any, then due by him, cease to be included in the membership of the Institution, and his name shall be removed forthwith by the Institution from its register.

20. If any Member, Associate Member, Graduate, Associate, or Affiliate, shall leave his subscription in arrear from one year, and shall fail to pay such arrears within three months, after a written application has been sent to him by the Secretary to his last known address, his name may be struck off the register by the Council at any time afterwards, and he shall thereupon cease to have any right as a Member, Associate Member, Graduate, Associate, or Affiliate, but he shall nevertheless continue liable to pay the arrears of subscription due at the time of his name being struck off; provided always that this article shall not be construed to compel the Council to remove any name if they shall be satisfied the same ought to be retained.

21. The Council may by a majority of the whole of the Councillors refuse to continue to receive subscriptions of any Member, Associate Member, Graduate, Associate, or Affiliate, and may remove his name from the register without assigning any reason for so doing, and he shall thereupon cease to be an Ordinary Member, Associate Member, Graduate, Associate, or Affiliate.

ENTRANCE FEES AND SUBSCRIPTIONS.

22. Each Ordinary Member shall pay an annual subscription of £2 10s.

23. Each Associate Member shall pay an annual subscription of £2.

24. Each Graduate shall pay an annual subscription of £1.

25. Each Associate shall pay an annual subscription of £2.

26. Each Affiliate shall pay an annual subscription of £5 per nomination. (See Article 11.)

27. All subscriptions shall be payable in advance, and shall become due on the 15th day of July in each year.

28. In the case of Ordinary Members, Associate Members, Graduates, Associates, and Affiliates, elected in the last three months of any year, the first subscription shall cover the year of election and the succeeding year.

29. Any Ordinary Member, Associate Member, or Associate, whose subscription is not then in arrears, may compound for the then current year and all future years by the payment of 25 guineas or such other amount as may be approved by the Council.

30. Every new Ordinary Member, Associate Member, Graduate, Associate, or Affiliate, may be required to pay an entrance fee on admission to the Institution, the amount of which shall be determined by the Council from time to time; but no payment, other than the increased annual subscription, shall be due on transference from one class to another.

31. Everyone admitted to the Institution, whether as Ordinary Member, Associate Member, Graduate, Associate, or Affiliate, shall be considered as belonging thereto, and as such liable to the payment of his annual subscriptions and other payments, until his name shall have been removed by the Institution from its register.

32. No Ordinary Member, Associate Member, Graduate, Associate, or Affiliate, whose contribution is six months in arrear shall be entitled to attend or take part in the meetings of the Institution, nor to receive the Institution printed papers, nor shall any such Ordinary Member, Associate Member, or Associate be entitled to vote. Any Ordinary Member, Associate Member, Graduate, Associate, or Affiliate, whose contribution is fifteen months in arrear, shall be deemed to have forfeited his claim to all privileges of the Institution, and his name may be removed from the register by order of the Council, but he shall nevertheless continue liable to pay the arrears of subscription due at the time of his name being so removed, provided always that this article shall not be construed to compel the Council to remove any name, if they be satisfied that the same should be retained.

33. The Council may at their discretion reduce or remit the annual subscription or the arrears of the annual subscription of any Ordinary Member, Associate Member, Graduate, Associate, or Affiliate.

COUNCIL. CONSTITUTION AND ELECTION OF.

34. The Council of the Institution shall be chosen from the Members only, and shall consist of one President, not more than six Vice-Presidents, twenty-one Ordinary Members of Council, not more than four Past-Presidents, and not more than three Past-Vice-Presidents, and the Chairman of every local Section of the Institution constituted in accordance with the Articles of Association who has become *ex-officio* a member of Council (plus such other members as the Local Section has become entitled under Article 66).

The Council of the Institution shall have power from time to time, if, in their opinion, it is desirable to do so, to co-opt as additional members of the Council not more than three persons, who shall be nominated by any other Society, Corporation, or Body which shall have kindred interests with or further or assist the objects of the Institution. Such additional members shall hold office for such period and on such terms as may be agreed upon by the Council and the nominating body.

35. The President, not less than half the Vice-Presidents, and seven Ordinary Members of Council, shall retire at each Annual General Meeting, but shall be eligible for re-election, but no President shall hold office longer than two years without a break.

36. The Vice-Presidents and Ordinary Members of Council to retire each year shall, unless the Council agree otherwise among themselves, be chosen from those who have been longest in office, and in cases of equal seniority shall be determined by ballot.

37. The Past-Presidents, the Past-Vice-Presidents to serve upon the Council shall be appointed annually by the Council. They shall retire at each Annual General Meeting, but shall be eligible for re-appointment.

38. All Vice-Presidents who have served as such for a total number of eight years shall at the next following Annual General

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Meeting cease to be Vice-Presidents, and shall become Past-Vice-Presidents, and other Vice-Presidents who have so served for a total number of six years may be appointed by the Council to be Past-Vice-Presidents, and shall on being so appointed cease to be Vice-Presidents.

39. The Council may supply any casual vacancy in the Council (including any casual vacancy in the office of President) which shall occur between one Annual General Meeting and another: and the President, Vice-Presidents, or Members of Council so appointed by the Council shall retire at the succeeding Annual General Meeting. Vacancies not filled up at any such meeting shall be deemed to be casual vacancies within the meaning of this Article.

40. Candidates for election as Councillors shall be nominated in writing at or before the General Meeting preceding the Annual General Meeting, when the Council shall present a list of their retiring members who are eligible, and willing to be re-elected. Any Ordinary Member or Associate Member shall be entitled to nominate candidates. The names, business and private addresses, occupations, and honorary titles of the candidates, together with the other Institutions to which they belong, shall be printed on a ballot list which shall be forwarded to the Ordinary Members and Associate Members at least seven days previous to the ballot being taken. The names of those elected to fill the offices of President and Vice-President and the names of the Chairman and of the Members of the Committees of the local centres elected by those Committees to represent them on the Council shall not be subject to ballot; but the names, addresses, titles, etc., of those so elected, together with the names of the non-retiring Councillors, shall be sent to the members with the ballot list. An Ordinary Member or Associate Member voting *against* a candidate shall strike out the name in accordance with the instructions on the ballot paper, as may be determined by the Council from time to time. Only those votes shall be effective which are recorded on lists reaching the Secretary by the specified date.

41. Candidates for the offices of President and Vice-President shall be nominated in writing by a Member of Council before the Council Meeting prior to that at which the election of President and Vice-Presidents takes place. They shall be elected by the

Council at a meeting held prior to the date of the Annual General Meeting, and shall hold office for a period of one year from the first Ordinary General Meeting of the Session following their election.

42. The first Council of the Institution shall consist of such as shall consent to act; the President and Councillors shall, save for resignation, hold office until the Annual General Meeting held in 1922. The Council so constituted may co-opt additional Councillors, provided that the number of the Council does not exceed that prescribed. Vacancies occurring between the one Annual General Meeting and the next may be filled by the Council.

PROCEEDINGS, POWERS, AND DUTIES OF THE COUNCIL.

43. The Council shall direct and manage the property and affairs of the Institution, and may regulate their own procedure, except that not less than five Councillors shall form a quorum. The Council may exercise all such powers of the Institution as might be exercised in General Meeting and the time being in force required, or by the Articles required or expressly directed to be exercised, or expressly declared to be exercisable by the Institution in General Meeting or with all the members of the Institution shall be bound by the acts and decisions of the Council subject nevertheless to any regulations of these Rules and to such regulations as may be prescribed by the Institution in General Meeting shall invalidate any prior Act of the Council which would have been valid if such regulation had not been made. Provided that the Council may with, but not without, the authority of a resolution of the Ordinary Members, Associate Members, and Associates in General meeting, borrow moneys for the purposes of the Institution on the Security of the property of the Institution or other available security, or otherwise, at their discretion.

44. The Council shall have power to consider and decide all matters not provided for by the Rules.

45. The Council shall at all times cause to be kept, in appropriate books, proper and sufficient accounts of the capital, funds, receipts, and expenditure of the Institution. The financial year

of the Institution shall end on the 15th July in each year; and a statement of the funds of the Institution and of the receipts and expenditure during such financial year shall be made, under the direction of the Council, each year, and after having been verified and signed by the auditors and approved by the Council shall be laid before the Annual General Meeting of the year following.

46. The Council may appoint Committees chosen from their own body, and Committees for special purposes consisting of members of the Council and Ordinary Members, Associate Members, Associates, and Affiliates of the Institution, and others, with such powers as the Council may prescribe. In the absence of the President, the Council or Committee shall elect a Chairman from among those present.

47. The President shall, *ex-officio*, be a member of all Committees of Council.

48. The Council, when they may consider it expedient to propose the enactment of any new Article, or the alteration or repeal of any existing one, shall summon the necessary Special General Meeting of Ordinary Members and Associate Members to decide the same; and the Council are at all times bound to summon such a Special General Meeting on a requisition, in writing, of ten per cent. but not less than fifty Ordinary Members, Associate Members, or Associates, specifying the particular new Article, or the alteration of an existing one, which they recommend.

49. It shall be the duty of the Council to adopt all due means for the advancement of the Institution; to provide for properly conducting its business in all cases of emergency; and to arrange for the publication, in such a way as they may deem desirable, of the papers read at meetings of the Institution, and discussions thereon, and of such documents as may be calculated to advance Production Engineering knowledge.

50. No act done by the Council, whether *ultra vires* of the Council or not, which shall have received the express or implied sanction of the Ordinary Members and Associate Members and Associates in General Meeting, shall be afterwards impeached by any person included in the membership of the Institution on

any ground whatever, but shall be deemed to be an act of the Institution, provided that, though *ultra vires* of the Council, it be within the powers of the Institution.

APPOINTMENT AND DUTIES OF OFFICERS.

51. The Treasurer of the Institution shall be appointed as and when a vacancy occurs by the Council, shall be removable by the Council upon one month's notice from any day, but in the case of serious negligence may be dismissed without notice. The Treasurer shall give one month's notice in the event of his wishing to resign.

52. The Treasurer shall hold and be responsible for the uninvested funds of the Institution; shall keep all the accounts necessary and proper for the purposes of the Institution; shall from time to time submit financial statements at the request of the Council; and shall pay all moneys into Bank, approved by the Council, upon receipt.

SECRETARY.

53. The Secretary of the Institution shall be appointed by the Council.

54. It shall be the duty of the Secretary, in person or by deputy, under the direction of the Council, to conduct the correspondence of the Institution; attend all meetings of the Institution and of the Council; take minutes of the proceedings of such meetings; to superintend the publication of such papers as the Council may direct; to have charge of the Library; and to conduct the collection of all subscriptions. He shall also engage and be responsible for all persons employed under him. He shall conduct the ordinary business of the Institution in accordance with these Rules and the direction of the President and Council.

AUDITORS.

55. The Auditors shall be elected annually by the Annual General Meeting, and shall be eligible for re-election on the expiration of their year of office.

56. It shall be left to the Council, as seems expedient to them from time to time, whether all or any of the Officers of the Institu-

tion be engaged for full or part time employment, and to fix their rate of remuneration, if any.

GENERAL MEETINGS.

57. The General Meetings shall consist of the Ordinary Meetings, the Annual General Meeting, and of Special Meetings, as hereinafter defined.

58. The Annual General Meeting shall take place in London in one of the first four months of every year. The Ordinary Meetings shall take place at such times and places as the Council shall determine.

59. A Special Meeting may be convened at any time by the Council, and shall be convened by them whenever a requisition, signed by 10 per cent., but not less than fifty Ordinary Members or Associate Members of the Institution, specifying the object of the Meeting, is left with the Secretary. If for fourteen days after the delivery of such requisition a Meeting be not convened in accordance therewith, the requisitionists, or 10 per cent. of the Ordinary Members or Associate Members of the Institution, and not less than fifty, may convene a Special Meeting in accordance with the requisition. All Special Meetings shall be held in London.

60. The quorum of the Annual General Meeting or of a Special Meeting shall be five. In the event of the quorum not being formed within half an hour of the time announced for the commencement of the Meeting, the Council shall be empowered to deal with the business of the Meeting.

61. Seven clear days' notice of every Meeting, specifying generally the nature of any special business to be transacted at any Meeting, shall be given to every person on the Register of the Institution, except as provided by Rule 77, in regard to Special Meetings, and Rule 79 in regard to General Meetings, and no other special business shall be transacted at such Meeting; but the non-receipt of such notice shall not invalidate the proceedings of such Meeting. No notice of the business to be transacted (other than such ballot lists as may be requisite in case of elections) shall be required in the absence of special business.

62. Special business shall include all business for transaction at a Special Meeting, and all business for transaction at every other Meeting, with the exception of the reading and confirmation of the Minutes of the previous Meeting, the election of Members, Associate Members, Graduates, Associates, and Affiliates, and the reading and discussion of communications and papers.

63. No person entered on the Register other than Ordinary Members, Associate Members, and Associates, shall have the right to vote at any Meeting of the Institution. Each Ordinary Member, Associate Member, and Associate shall have one vote. Honorary Members and Graduates and Affiliates shall not have votes at Meetings of the Institution.

LOCAL SECTIONS.

64. Local Sections of the Institution may be formed by the Council, consisting of Members, Associate Members, Graduates, Associates, and Affiliates of the Institution, in such local centres as afford evidence satisfactory to the Council :—

(*a*) Of a demand for the formation of a Local Section on the part of Members and Associate Members resident in the locality, and

(*b*) That a Local Section, if formed, will be so adequately supported and of such use to the Members, Associate Members, Graduates and Associates, and Affiliates in the locality that the Council will be justified in appropriating funds of the Institution towards its support.

The Council shall have power to dissolve such Section at any time after it has been formed.

65. The proposal for the formation of a Local Section shall be by petition of the Members and Associate Members resident in the locality. Such petition, together with the evidence as to the probable support and usefulness of the proposed Section, shall be brought before and considered by the Council, and if they decide that the Section shall be formed, a first Meeting of the Members, Graduates, Associates, and Affiliates resident in the locality shall be convened by written notice specifying generally the nature of the business to be transacted.

This Meeting shall be under the Chairmanship of a Member of the Council.

66. A Chairman of the Section (chosen from the Members only) and a Committee (chosen from the Members and Associate Members) for the management of the local affairs of the Section, subject to the approval of the Council, shall be appointed by resolution of the Members, Associate Members, and Associates resident in the locality at the first Meeting of the Section. To ensure proportional representation on the Council, the Chairman shall become *ex-officio* a member of Council, and where the Local Section is of such importance numerically the Section shall become entitled to elect such other members of their Committee as shall ensure the Section proportional representation on the Council. The Chairman and at least one-third of the Committee, including the additional representative to the Council, if any, shall retire at each Annual Meeting of the Section. Such retirement shall cancel their representation on the Council, but all members shall be eligible for re-election. Casual vacancies in the office of Chairman or in the Committee may be filled by the Committee, but those so appointed by them shall retire at the succeeding Annual Meeting of the Section. The election of a Chairman and members of the Committee (qualified as above) to supply the place of those retiring shall be conducted in manner prescribed by the Rules from time to time in force, as provided by Rule 67.

67. Each Local Section shall be constituted and its affairs shall be carried on in accordance with rules and regulations laid down from time to time by the Council.

68. The appropriation and contribution of funds of the Institution towards the expenses of Local Sections, or to enable such Local Sections to co-operate with Sections of other Institutions and Technical and Scientific Societies in the same locality for the purpose of forming Local Associations for the acquisition of Local Technical Libraries and Meeting Rooms and the provision of staff and equipment thereat for the common use of such Local Sections and Societies, consistently with the objects of the Institution, shall be in the sole discretion of the Council, and the Institution shall not be responsible for any liability incurred by or on behalf of any Local Section of the Institution or by or

on behalf of any such Local Association beyond any amount previously appropriated or contributed for any such specified purpose by the Council.

69. The Council may, subject to ratification at a General Special Meeting convened for the purpose, arrange for the union, alliance, or incorporation with the Institution of any Society with kindred objects; and may also, if they think fit, remit or reduce the entrance fees of the Members of such Society at the time of union, alliance, or incorporation.

PROPERTY AND FUNDS.

70. The property and funds of the Institution, and generally all its personal estate and all its real estate (if any) may be sold or disposed of by or according to the order and discretion of the Council, but only if and provided that it be sanctioned by a Special General Meeting of Ordinary Members, Associate Members, and Associates.

71. Any donation may be accepted by the Council and Treasurer in aid of the funds of the Institution.

72. All the moneys of the Institution in excess of such current balance in the hands of the Treasurer as the Council shall from time to time require the Treasurer to keep in hand to meet the current expenses of the Institution, shall be invested in any mode in which Trustees are or shall be by law, in absence of special direction, authorised to invest trust moneys under their control.

73. Every paper presented to the Institution, and accepted for reading or for publication in the "Proceedings," and the copyright thereof, shall be the property of the Institution, unless there shall have been some previous arrangement to the contrary. But the Council, in such cases as they may think fit, shall have power to release or surrender their rights in respect of any such paper or the copyright thereof.

74. Each Councillor shall be accountable in respect of his own acts only, and shall not be accountable for any acts done or authorised to which he shall not have expressly assented. No Councillor shall incur any personal liability in respect of any loss or damage incurred through any act, matter, or thing done,

authorised, or suffered by him, being done in good faith for the benefit of the Institution, if believed by him to be within although in excess of his legal power.

NOTICES.

75. A notice may be served by the Council or Secretary of the Institution upon any Honorary Member, Ordinary Member, Associate Member, Graduate, Associate, or Affiliate, either personally or by sending it through the post in a prepaid letter addressed to such Honorary Member, Ordinary Member, Associate Member, Graduate, Associate, or Affiliate, at his address, as registered in the books of the Institution.

76. Any notice, if served by post, shall be deemed to have been served at the time when the letter containing the same would be delivered in the ordinary course of the post; and in proving such service it shall be sufficient to prove that the letter containing the notice was properly addressed and put into the Post Office.

77. No Honorary Member, Ordinary Member, Associate Member, Graduate, Associate, or Affiliate, not having a registered address within the United Kingdom, shall be entitled to any notice; and all proceedings may be had and taken without notice to such Honorary Member, Ordinary Member, Associate Member, Graduate, Associate, or Affiliate, in the same manner as if he had had due notice.

78. The Institution may appoint a periodical as the Official Organ of the Institution, for the publication of general notices and other information at the discretion of the Council.

79. After seven clear days from the date of publication any notice published in the Official Organ of the Institution shall be deemed to have been served on all Members.

80. These Rules may be altered by resolution of General Meeting at any time provided that in the notice calling such meeting it is stated that the alteration of Rules forms part of the business to be transacted.

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